

AD A108803

RMS-81-R-1

12

LEVEL II

TAPED RANDOM SPECTRA FOR RELIABILITY DEMONSTRATION TESTING

Joseph J. Popolo, John G. Devitt, Richard Pokallus
and Noe Arcas
Grumman Aerospace Corporation
Bethpage, N.Y. 11714

April 1981

Final Report for Period October 1979-April 1981
Approved for public release; distribution unlimited

Prepared for

NAVAL ELECTRONICS SYSTEMS COMMAND
Washington, D.C. 20360

DTIC
ELECTE
DEC 23 1981
B

DTIC FILE COPY

81 12 23 139

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER RMS-81-R-1	2. GOVT ACCESSION NO. ADA108803	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Taped Random Spectra for Reliability Demonstration Testing		5. TYPE OF REPORT & PERIOD COVERED Final Report, Oct 79-April 81
7. AUTHOR(s) Joseph J. Popolo, Richard Pokallus, John G. Devitt, Noe Arcas		6. PERFORMING ORG. REPORT NUMBER RMS-81-R-1
9. PERFORMING ORGANIZATION NAME AND ADDRESS Grumman Aerospace Corp. Bethpage, New York		8. CONTRACT OR GRANT NUMBER(s) N00019-77-C-0032
11. CONTROLLING OFFICE NAME AND ADDRESS NAVELEX (ELEX 813) NC-1 Washington, D.C. 20360		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE April 1981
		13. NUMBER OF PAGES
		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Reliability test profiles; reliability demonstration testing; taped random; microprocessor; multiplexer		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This study was undertaken to develop an economical test technique for Reliability Demonstration tests in accordance with MIL-STD-781C. This has been accomplished by developing two different methods: <ul style="list-style-type: none"> • Multiplex System - incorporates a reel-to-reel tape recorder that generates the desired synthesized random spectrum on one channel while the other channel incorporates a control programmer. • Microprocessor System - incorporates a desk top computer that is programmed to initiate, monitor and control a Reliability Demonstration test. Included with this system is a "sound-on-sound" tape cassette recorder to generate the synthesized random spectrum and a printer to record the control signals and monitor data during the test. 		

DD FORM 1473

EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6461

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

PREFACE

This Final Technical Report was prepared by Grumman Aerospace Corporation, Bethpage, New York, under Contract N00019-77-C-0032, for the Naval Electronics Systems Command, Washington, D. C. Mr. William E. Wallace, Jr. (ELEX 813) was the Project Engineer for NAVELEX.

The effort described was accomplished during the period from October 1979 through April 1981.

The authors wish to acknowledge the outstanding contributions of Mr. George Hirschberger, who initiated and directed this program with enthusiasm and understanding until his untimely death in August, 1980.

NOTE: The tests described in this report make reference to the specific equipment employed. It is understood that other manufacturers' equipment of the same capability may always be substituted.

Accession For	
NTIS GRA&I	<input checked="checked" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A	

SUMMARY

This study was undertaken to develop an economical test technique to perform Reliability Demonstration tests in accordance with MIL-STD-781C. In order to accomplish the above, two different methods were evaluated:

- Multiplex System - incorporating a two-channel reel-to-reel tape re-recorder that generates the desired synthesized random vibration spectrum on one channel while the other channel incorporates a control program containing a series of single frequency sinusoidal signals which trigger simple ON/OFF commands to initiate the Reliability Demonstration test functions.

The total cost associated with the Multiplex system is approximately \$3500. This includes the purchase of the reel-to-reel recorder, the components to assemble the display panel, miscellaneous material, and the labor cost to assemble the entire system.

- Microprocessor System - incorporating a desk top computer that is programmed to initiate, monitor and control a Reliability Demonstration test. Included with this system is a "sound-on-sound" tape cassette recorder to generate the synthesized random spectrum as well as record the measured acceleration and a printer to record the control signals and monitor data during the test.

The Microprocessor system cost was approximately \$15,000, considerably more expensive than the Multiplex system. However, it contains essentially unlimited capability that will reduce expensive manpower and equipment failure diagnostic costs. The \$15,000 figure includes the purchase of the microprocessor printer, cassette recorder, tapes, A-D converter, I/O boards, miscellaneous components and the manpower costs to assemble the system.

In addition, this study provides two detailed procedures to provide the user with the necessary information to perform Reliability Demonstration Tests in accordance with MIL-STD-781C. Appendix A describes the Multiplex System and Appendix B describes the Microprocessor System.

CONTENTS

<u>Section</u>	<u>Page</u>
PREFACE	iii
SUMMARY	v
1 INTRODUCTION	1-1
1.1 Background	1-1
1.2 Objectives	1-1
1.3 Approach	1-4
2 TECHNICAL DISCUSSION	2-1
2.1 Introduction	2-2
2.1.1 Aircraft Mission Duration	2-2
2.1.2 Aircraft Mission Profile	2-3
2.1.3 Test Variables and Tolerances	2-6
2.1.4 Reliability Demonstration Test Profile	2-6
2.1.5 Taped-Random Technique	2-6
2.2 Test Setup and Equipment	2-10
2.2.1 Test Article	2-10
2.2.2 Electrodynamic Exciter System	2-10
2.2.3 Environmental Test Chamber	2-11
2.2.4 Test Setup	2-12
2.2.5 Sine Transfer Characteristics	2-12
2.3 Multiplex System	2-19
2.3.1 Approach	2-19
2.3.2 Tape Deck Evaluation	2-19
2.3.3 System Design	2-20
2.3.4 System Programming	2-40
2.3.5 System Operation	2-60
2.3.6 Conclusions and Recommendations	2-65

CONTENTS (contd)

<u>Section</u>	<u>Page</u>
2.4 Microprocessor System	2-66
2.4.1 Approach	2-66
2.4.2 Tape Deck Evaluation	2-68
2.4.3 System Design	2-71
2.4.4 System Programming	2-83
2.4.5 System Operation	2-110
2.4.6 Conclusions and Recommendations	2-117
3 RECOMMENDATIONS AND CONCLUSIONS	3-1
<u>Appendix</u>	
A MULTIPLEX SYSTEM PROCEDURE	A-1
B MICROPROCESSOR SYSTEM PROCEDURE	B-1

ILLUSTRATIONS

<u>Figure</u>		<u>Page</u>
1-1	Reliability Demonstration Study Task Flow Diagram	1-5
2-1	Nominal Random Vibration Test Spectrum and Tolerances for Reliability Demonstration	2-5
2-2	Reliability Demonstration Test Profile	2-9
2-3	Test Chamber Interface Diagram	2-13
2-4	Test Setup	2-14
2-5	Sine Transfer Characteristics E/G, Measured at Room Temperature	2-15
2-6	Sine Transfer Characteristics E/G, Measured at -54°C	2-16
2-7	Sine Transfer Characteristics E/G, Measured at +71°C	2-17
2-8	Effect of Temperature on Sine Transfer Characteristics E/G.	2-18
2-9	Multiplex Mainframe Chassis	2-21
2-10	Average Frequency Response Curve for Pioneer RT 909 Tape Deck	2-22
2-11	Multiplex System Block Diagram	2-25
2-12	Input Power Circuit	2-26
2-13	Typical Control Circuit.	2-27
2-14	Multiplex Front Panel	2-31
2-15	Meter and Control Circuits	2-32
2-16	Clock Circuits	2-35
2-17	Clock Circuit Connector Wiring	2-36
2-18	Acceleration Overtest Audio Alarm, Multiplex Mainframe	2-38
2-19	Tape Frequency Programmer, Front and Rear Panels	2-39
2-20	Tape Programmer, Typical Oscillator Circuit	2-42
2-21	Multiplex Test System	2-43
2-22	Multiplex System Console	2-44
2-23	Reliability Demonstration Profile #1, 8-hr Program, Dry Bulb Temperature: -65°F to 160°F	2-45

ILLUSTRATIONS (contd)

<u>Figure</u>		<u>Page</u>
2-24	Reliability Demonstration Profile #1, 8-hr Program, Wet Bulb Temperature: +50° to +100°F	2-46
2-25	Multiplex System: Recorded Random Voltage, Temperature Compensated	2-54
2-26	Reliability Demonstration Test Profile - Short Demo	2-57
2-27	Cannon Firing Time History, High Firing Rate, Vertical Axis Transient Capture	2-58
2-28	Cannon Firing Time History, Low Firing Rate, Vertical Axis Transient Capture	2-59
2-29	Multiplex Test Operation with 8-Hour Program	2-61
2-30	Multiplex System Spectrum Analysis of Control Accelerometer, 2/6/81	2-62
2-31	Multiplex System Spectrum Analysis of Control Accelerometer, 3/19/81	2-64
2-32	Average Frequency Response Curve for TEAC-124M Tape Deck	2-70
2-33	Microprocessor and Printer	2-77
2-34	Microprocessor Test System	2-85
2-35	Microprocessor Components in Multiplex Console	2-86
2-36	Microprocessor Tape Deck in Multiplex Console.	2-87
2-37	CALIBRATE Flowchart.	2-89
2-38	SETUP Flowchart.	2-91
2-39	DEMO Flowchart: Stabilization Routine	2-93
2-40	DEMO Flowchart: Profile Monitor and Control	2-94
2-41	DEMO Flowchart: Profile Monitor and Control (Cont.)	2-95
2-42	DEMO Flowchart: Hold Routine	2-96
2-43	TROUBLESHOOT Flowchart	2-99
2-44	Demonstration of Microprocessor Tape System	2-102
2-45	Microprocessor Demonstration Program	2-103
2-46	Microprocessor System: Recorded Random Voltage, Temperature Compensated	2-111
2-47	Inserting Program Disk Into Microprocessor	2-112
2-48	Microprocessor System Playback of Control Accelerometer from Tape Loop	2-115

ILLUSTRATIONS (contd)

<u>Figure</u>		<u>Page</u>
2-49	Microprocessor System Compensated Playback of Control Accelerometer from Tape Loop	2-116
2-50	Microprocessor System Spectrum Analysis of Control Accelerometer, 3/19/81	2-118

TABLES

<u>Table</u>		<u>Page</u>
2-1	Aircraft Mission Duration	2-4
2-2	Test Variable Characteristics	2-7
2-3	Frequency Allocation	2-23
2-4	Connector Pin Designations	2-29
2-5	Tabulation Sheets for Synthetic Random Spectrum	2-47
2-6	H/P 5427A Vibration Control System Program.	2-51
2-7	Multiplex System - Reliability Demonstration Test Event Schedule	2-55
2-8	Multiplex System - Short Duration Demonstration Test Event Schedule	2-61
2-9	Manufacturer's Specification for Exorset 30	2-73
2-10	Manufacturer's Specification for A-D Module	2-79
2-11	Manufacturer's Specifications: a) D-A Module, b) Solid-State Delays	2-80
2-12	Manufacturer's Specifications for Printer	2-82
2-13	Program Names and Functions	2-88
2-14	Reserved Memory Locations	2-88
2-15	Program CALIBRATE	2-90
2-16	Program SETUP	2-92
2-17	Program DEMO	2-97
2-18	Program TROUBLESHOOT	2-100
2-19	Microprocessor Control System Printout	2-103
2-20	TROUBLESHOOT Program Segments	2-106
2-21	Program - RELDEM	2-107
3-1	Comparison of Systems	3-2

1 - INTRODUCTION

With the introduction of Military Standard MIL-STD-781C in October of 1977, a mission analog test profile approach was required for Reliability Demonstration testing. The purpose behind this approach is to more realistically simulate actual field operations of equipment. However, this new approach is considerably more expensive than the MIL-STD-781B tests previously performed. In particular, the high test costs can be directly associated with the following two major considerations:

- The requirement that random vibration be utilized for evaluating equipment installed in jet aircraft necessitates the use of an expensive vibration test facility plus highly skilled operating personnel
- The precise sequencing necessary to assure that vibration, moisture injection and equipment operation are applied at the proper time with respect to ambient temperature and cooling air temperature/airflow variations. This sequencing suggests that some form of function programming and monitoring could be included to supplement manual operator control.

The development of a test technique which would permit an economical generation of random vibration and which would also provide the automated sequencing, monitoring and control functions, would reduce the capital equipment costs as well as the highly skilled personnel deterrents associated with this type of test. Grumman's investigations indicate that the use of an audio taped program of random vibration, supplemented by a low-cost multiplexing or microprocessing device, could provide a practical and economical technique for conducting Reliability Demonstration tests in accordance with MIL-STD-781C.

1.1 BACKGROUND

Reliability Demonstration tests have classically been performed in accordance with MIL-STD-781B and have required that a repetitive thermal cycle approximately six hours long be coupled with a ten-minute period of low-level sinusoidal

single-frequency vibration applied during the equipment "on" portion of the thermal cycle. The specific thermal and vibration requirements from MIL-STD-781B, Military Standard, Reliability Tests: Exponential Distribution, dated 15 November 1967, are as follows:

"Temperature Cycling-----Temperature cycling shall be time to stabilize at low temperature followed by time to stabilize at the high temperature, plus 2 hours."

"Vibration-----2.2G \pm 10% peak acceleration value at any non-resonant frequency between 20 and 60 cps measured at the mounting points on the equipment. The duration of vibration shall be at least 10 minutes during each hour of equipment operating time."

The current mission analog approach, as defined in MIL-STD-781C, Military Standard, Reliability Design Qualification and Production Acceptance Tests: Exponential Distribution, dated 21 October 1977, requires the generation of random vibration for a major portion of the test, a period ranging from hundreds to thousands of hours, depending on the mean-time-between-failure (MTBF) requirement. Further, a maximum of four variations in the given random vibration spectrum could be required during any specific Reliability Demonstration test. In addition to the random vibration, moisture injection, temperature, power, etc., must be precisely sequenced to be consistent with the mission environmental profile.

Grumman, under contract to NAVELEX, previously developed a procedure for taping random vibration spectra and for utilizing these tapes to drive electrodynamic exciter systems (Ref. NAVMAT P-9492). This procedure, although addressing short term (ten-minute) vibration acceptance test requirements, has shown that the concept is economically feasible and practical. The duration is limited only by the type of tape deck employed. Further, sequencing of other test operations may be accomplished by utilizing unused tape deck channels and multiplexing taped signals to trigger other functions at appropriate time intervals. The sequencing may also be accomplished by programming a microprocessor with

the desired schedule and then using the stored information to start, stop and monitor all test parameters, including the tape deck (which generates the random vibration spectrum). Preliminary investigations indicate that microprocessing devices which can be adapted for use in the application are available commercially from a number of sources.

Use of a tape deck system to generate random vibration provides significant economic advantages when employed during Acceptance tests. It could also provide additional, even more significant advantages, when utilized for generating random vibration during the long-duration more complex Reliability Demonstration tests.

- A tape, embodying all necessary spectra, could be "cut" once and the many repetitions required would be generated invariantly for the duration of the test
- The high skill level of a trained random vibration specialist would not be required and monitoring could be accomplished by any laboratory technician
- The tape deck, either used as a multiplexer/programmer or coupled with a microprocessor, would provide a simple, inexpensive system, capable of sequencing all test parameters
- Even if a manufacturer owned a random vibration test facility, the tape approach would provide him with the flexibility to use the tape deck system and not dedicate his random facility to a lengthy demonstration test.

1.2 OBJECTIVES

The previous study program conducted for NAVELEX showed that the taped approach for programming random vibration is feasible and practical for conducting short-term Acceptance vibration testing. It was the intent of this new study to determine the precise requirements, both in equipment and procedures, and to expand the concept for long-duration Reliability testing including programmed sequencing of all test parameters. The principle objectives of this study were:

- Investigate and define required Reliability Demonstration test parameters

- Determine specific equipment requirements and availability for:
 - Conducting long-term random vibration Reliability Demonstration tests
 - Developing a multiplex programming system
 - Developing a microprocessor programming system
- Evaluate both the multiplex and microprocessor systems through actual laboratory tests
- Prepare a final report which will compare the two methods, and include guidelines for their application
- Prepare a detailed procedures document describing the steps necessary for the application of each technique.

1.3 APPROACH

The total effort was divided into four tasks, chronologically phased to complement each other and assist in the evaluation of their predecessors. Figure 1-1 describes in block diagram form the various tasks and their relationships. The four tasks were:

TASK A: DEFINITION OF TEST PARAMETERS

- Review existing documentation, i.e., MIL-STD-781C, Naval Research Laboratory study reports in support of MIL-STD-781D, etc., to establish the specific environments, including magnitudes and durations, which will be used during Reliability Demonstration testing
- Evaluate the test parameters that must be applied using the multiplex system and the processor sequencing system.
- Establish a programming logic chart for each test method.

TASK B: EQUIPMENT REQUIREMENTS AND AVAILABILITY

- Establish specific equipment requirements:
 - Long duration random vibration tests; cassette, video or reel-to-reel tape decks

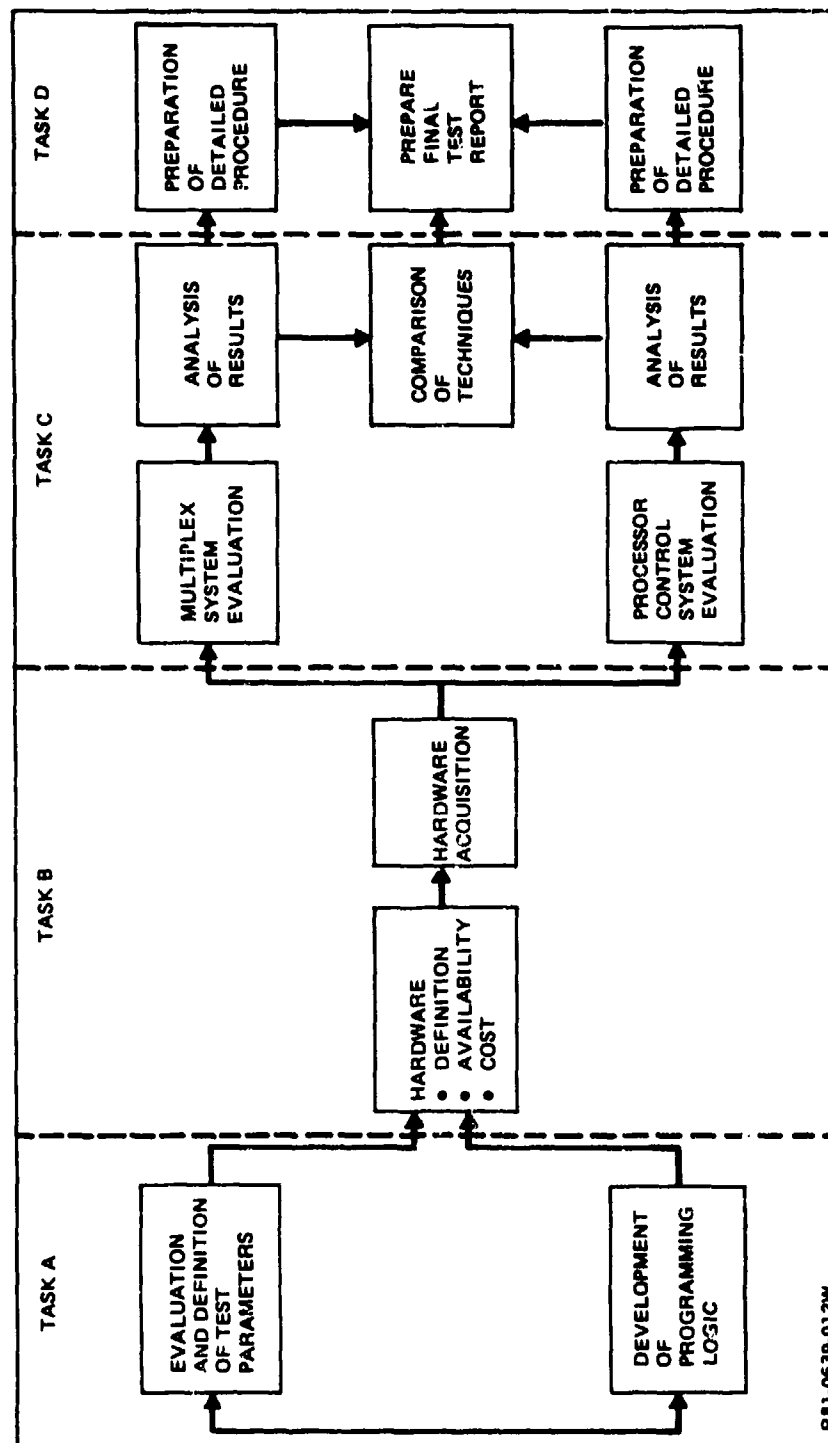


Fig. 1-1 Reliability Demonstration Study Task Flow Diagram

- Multiplex System: Establish test parameters using a taped approach; frequency discrimination, relay interface, etc.
- Microprocessor System: Develop sequencing, microprocessor, sensors, interface units, etc.
- Determine the commercial availability and cost of the required hardware through a review of current literature and direct contact with equipment manufacturers
- Obtain hardware: microprocessor, tape deck, frequency discriminators, interface relays, etc.

TASK C: EVALUATION OF TECHNIQUES

- Conduct an evaluation and verification program of both the multiplexed and the microprocessor-controlled systems
- Obtain required hardware, assemble systems and verify operation
- Evaluate methods of programming the tape system and develop a methodology for sequencing the tape
- Investigate methods of interfacing the exciter system, environmental controls, instrumentation, support and test article checkout equipment with each of the techniques proposed
- Perform a verification test using the environmental test profile established
- Evaluate and analyze test results with regard to applicable tolerances, safety, reliability, cost and ease of system operation.

TASK D: DOCUMENTATION

- Prepare a final report which summarizes the results of the study and compares the two methods developed (multiplexed and microprocessor-controlled systems)
- Prepare a step-by-step procedure which details the application of each of the two techniques.

2 - TECHNICAL DISCUSSION

The objective of this program was to develop inexpensive techniques to perform Reliability Demonstration tests in accordance with MIL-STD-781C. The requirements of this specification dictate the need to conduct combined long-duration environmental tests on electronic equipment, incorporating random vibration, temperature cycling and humidity inputs.

The random vibration was applied using a standard electrodynamic exciter system that was driven by utilizing the procedures of the taped-random technique described in NAVMAT P-9492 (Navy Manufacturing Screening Program). This method utilizes a stereo tape deck and pre-programmed tape to produce the desired test spectrum, and is summarized in Para 2.1.5 herein.

The temperature and humidity environments were introduced using a standard environmental test chamber with the necessary controls to vary inputs as desired.

In this study, two system control approaches were evaluated to optimize the marriage between the chamber control system and the desired duration of the specified test cycle. These two approaches were:

- (1) The multiplex approach for test chambers that already have a programming device, such as a cam, to take care of mission profiles less than 12 hours (typically, aircraft missions). This method is described in Subsection 2.3
- (2) The microprocessor approach, for test chambers that either have no programming device or one for only short-duration tests. The intent was to provide programming capability for long-duration missions (typically weeks, such as shipboard missions). This method is described in Subsection 2.4.

2.1 INTRODUCTION

In parallel with the evaluation of the multiplex and microprocessor system an effort was undertaken to develop a Reliability Demonstration Test Profile that would be representative of an aircraft mission. This final environmental profile will include the various mission-duration environmental parameters as well as incorporate the procedures outlined in MIL-STD-781C.

2.1.1 Aircraft Mission Duration

In this study program, it was decided to develop a Reliability Demonstration Test System that would encompass the maximum practical mission duration. This profile could then be recycled as many times as necessary in order to fulfill the contractual MIL-STD-781C Reliability Demonstration Test requirements.

To establish the test duration, 431 different missions from 32 Air Force aircraft and 17 different Navy aircraft were examined. The initial part of this investigation was to examine the Standard Aircraft Characteristics (SAC) document for each aircraft, to determine both the type of missions flown and the associated durations. In many situations, due to the micro-miniaturization and sophistication of aircraft electronic equipment, modern aircraft have the capability of conducting several separate and independent missions⁽¹⁾. Additionally, during each mission the various maneuvers cause a change in the environmental parameters.

Specific interrelated factors that impact the various flight conditions are:

- Aircraft capability
- Threat/target type
- Enemy tactics
- Range
- Armament carried
- Fuel loading
- Pilot preference
- Topography
- Weather

1. Dantowitz, A. and Hirschberger, G.; Development of Environmental Profiles for Testing Equipment Installed in Naval Aircraft; Final Report RMS-79-R-1 dated Sept. 1977 - Sept. 1978; Contract N00014-77-C-0662.

It was therefore decided to concentrate this effort on arriving at the maximum practical mission length and then develop a Reliability Demonstration Profile that incorporated the variations in environmental and operational parameters required by MIL-STD-781C.

Table 2-1 contains an accumulation of the data for aircraft flight durations versus number of missions. Since the majority of missions are three- to four-hour duration, four hours was chosen to be most representative of the average mission length. The final test duration was increased to eight hours because MIL-STD-781C requires each test cycle to consist of two missions. One mission starts from a cold environment and returns to a hot environment. The second starts in a hot environment and returns to a cold environment.

2.1.2 Aircraft Mission Profile

With the test cycle duration established at eight hours, an analysis was performed using the guidelines of MIL-STD-781C to determine the specific environmental stress levels for each of the mission flight phases, e.g., take-off, climb, combat, landing, etc. as well as for ground conditions.

After examination of the above parameters, each event is defined and the following data were collected:

- Duration (minutes)
- Compartment Temperature ($^{\circ}\text{C}$)
- Temperature Rate of Change ($^{\circ}\text{C}/\text{MIN}$)
- Vibration - W_o (g^2/Hz)
- Dew Point Temperature ($^{\circ}\text{C}$)
- Equipment Operations

Subsequently, the four most-severe vibration levels (W_o) were chosen to represent the typical aircraft mission, and the exposure time for each event was proportioned accordingly. Figure 2-1 defines the nominal random vibration spectrum for the Reliability Demonstration Test. Each of the four vibration conditions have the same spectrum but vary in the W_o and W_1 (g^2/Hz) values.

Table 2-1 Aircraft Mission Duration

MISSION DURATION, HR	NO. OF MISSIONS	CUM. NO. OF MISSIONS
0 - 1	21	21
1 - 2	84	105
2 - 3	102	207
3 - 4	100	307
4 - 5	50	357
5 - 6	21	378
6 - 7	7	385
OVER 7*	46	431
TOTAL		431
*MAX. MISSION DURATION: 17.1 HR (KC-135A) R81-0639-045W		

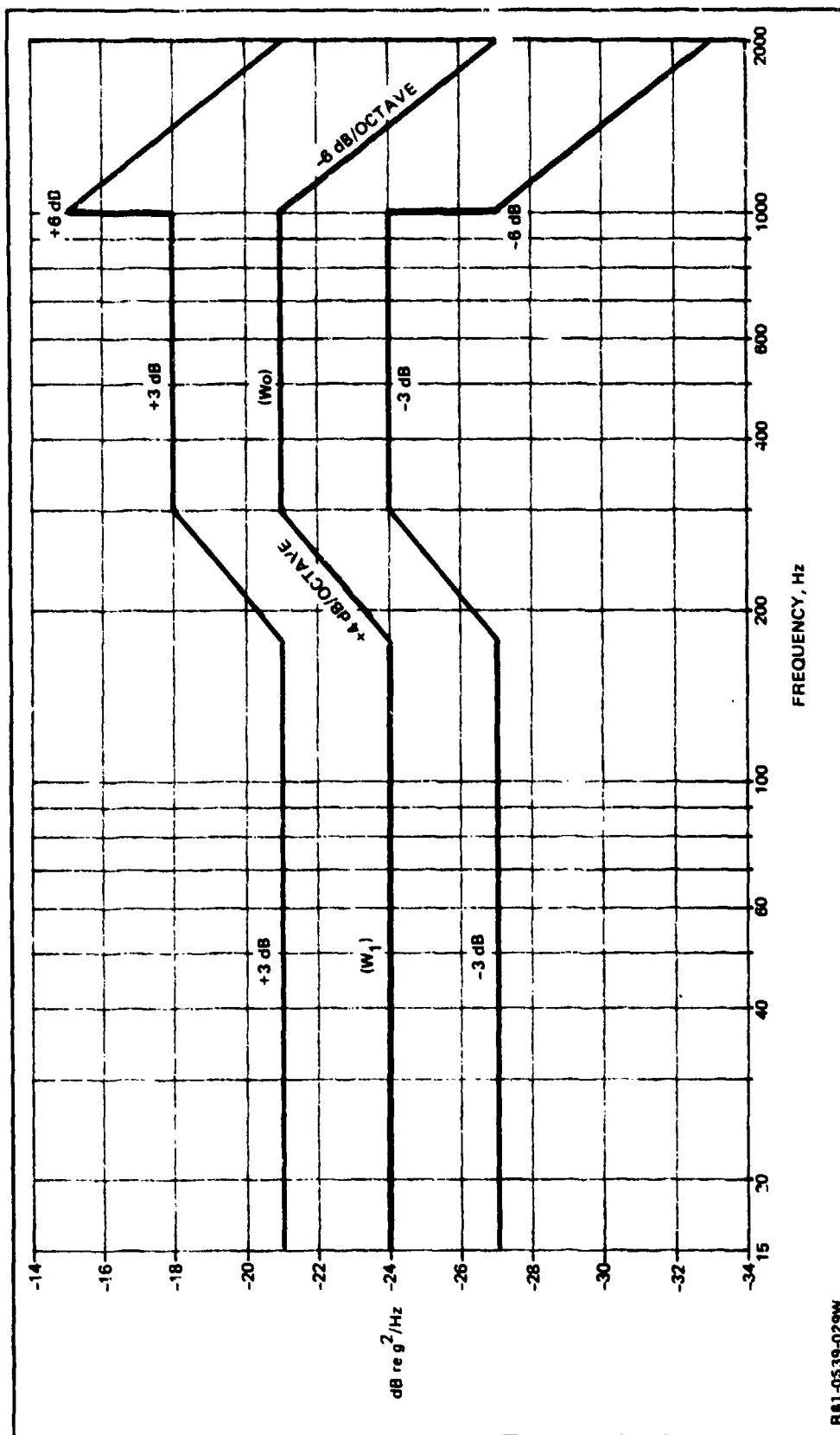


Fig. 2-1 Nominal Random Vibration Test Spectrum and Tolerances for Reliability Demonstration

The four levels chosen to describe the vibration environment are shown below:

CASE	W ₀ (g ² /Hz)	W ₁ (g ² /Hz)	Grms
1	.001	.0005	1.17
2	.0025	.0012	1.83
3	.004	.002	2.34
4	.008	.004	3.31
R81-0639-044W			

Relative to the final Reliability Test profile, the only modification to the typical mission is that at the start of both the cold and hot day cycle, a temperature soak of 30 minutes is required with equipment power off.

2.1.3 Test Variables and Tolerances

The establishment of the environmental and operational requirements are defined by utilizing the procedures of MIL-STD-781C, and the typical mission duration described herein. The test tolerances on test conditions, where applicable, have been obtained from paragraph 3.1.2, of MIL-STD-810.C. Table 2-2 describes in detail the various characteristics of each parameter and what functions they are to accomplish.

2.1.4 Reliability Demonstration Test Profile

The final establishment of the Reliability Demonstration Test Profile is shown in Figure 2-2, and includes the temperature, vibration, equipment operation and wet bulb requirements. All of the operations are synchronized so that each of the combinations of events are activated at the precise time specified in the profile.

The profile described here was incorporated into the Reliability Demonstration Test conducted to evaluate the operational characteristics of both the Multiplex and Microprocessor systems.

2.1.5 Taped-Random Technique

The taped-random technique uses an inexpensive stereo tape deck incorporating a pre-shaped random voltage spectrum to drive an electrodynamic exciter.

Table 2-2 Test Variable Characteristics

PARAMETER	RANGE	TOLERANCE	INPUT SIGNAL	FUNCTION TO BE ACCOMPLISHED	REMARKS
CHAMBER DRY BULB TEMPERATURE	-54 TO +71°C	±2.2°C	THERMOCOUPLE (MILLIVOLTS)	INITIATE-MONITOR-CONTROL	WET BULB CONTROLLED ONLY AT DRY BULB OF 71°C BETWEEN 260 → 290 MIN.
CHAMBER WET BULB TEMPERATURE	UNCONTROLLED TO 37.5°C	+10°C -0°C	THERMOCOUPLE (MILLIVOLTS)	INITIATE-MONITOR-CONTROL	
TEST ARTICLE POWER	N/A	N/A	VOLTS	TURN ON/TURN OFF	
VIBRATION	1.17 TO 3.31 GRMS	±10%	ACCELEROMETER (MILLIVOLTS)	INITIATE-MONITOR	
SUPPLEMENTAL COOLING AIR	-	-	VOLTS	TURN ON/TURN OFF	
• TEMPERATURE	N/A	N/A			
• MASS FLOW	N/A	N/A			
EQUIPMENT VOLTAGE VARIATION	NOMINAL MIN MAX	N/A N/A	VOLTS		
R81-0639-046W					

The technique, as discussed in NAVMAT-P-9492, requires six simple steps:

- (1) Configure the exciter and test article exactly as they will be for the actual Reliability Demonstration test.
- (2) Perform a 1-g sine sweep over the test frequency range with the control accelerometer recorded on the left channel of the tape deck, and the oscillator voltage input to the shaker power amplifier recorded on the right channel of the tape deck.
- (3) Play back the tape through a real-time analyzer and obtain the sine transfer characteristics (Power Amplifier Input Voltage divided by Control Acceleration) of the system.
- (4) Combine analytically the sine transfer characteristics with the required test spectrum, tape deck characteristics, and any compensation factors that are required to derive a synthetic random voltage spectrum.
- (5) Shape the synthetic random voltage using a random equalization system and record on the tape.
- (6) Play the tape through the shaker system to produce the required test spectrum.

The specific data on the synthetic random voltage derived for this program is detailed in Para. 2.2.5 and 2.3.4.

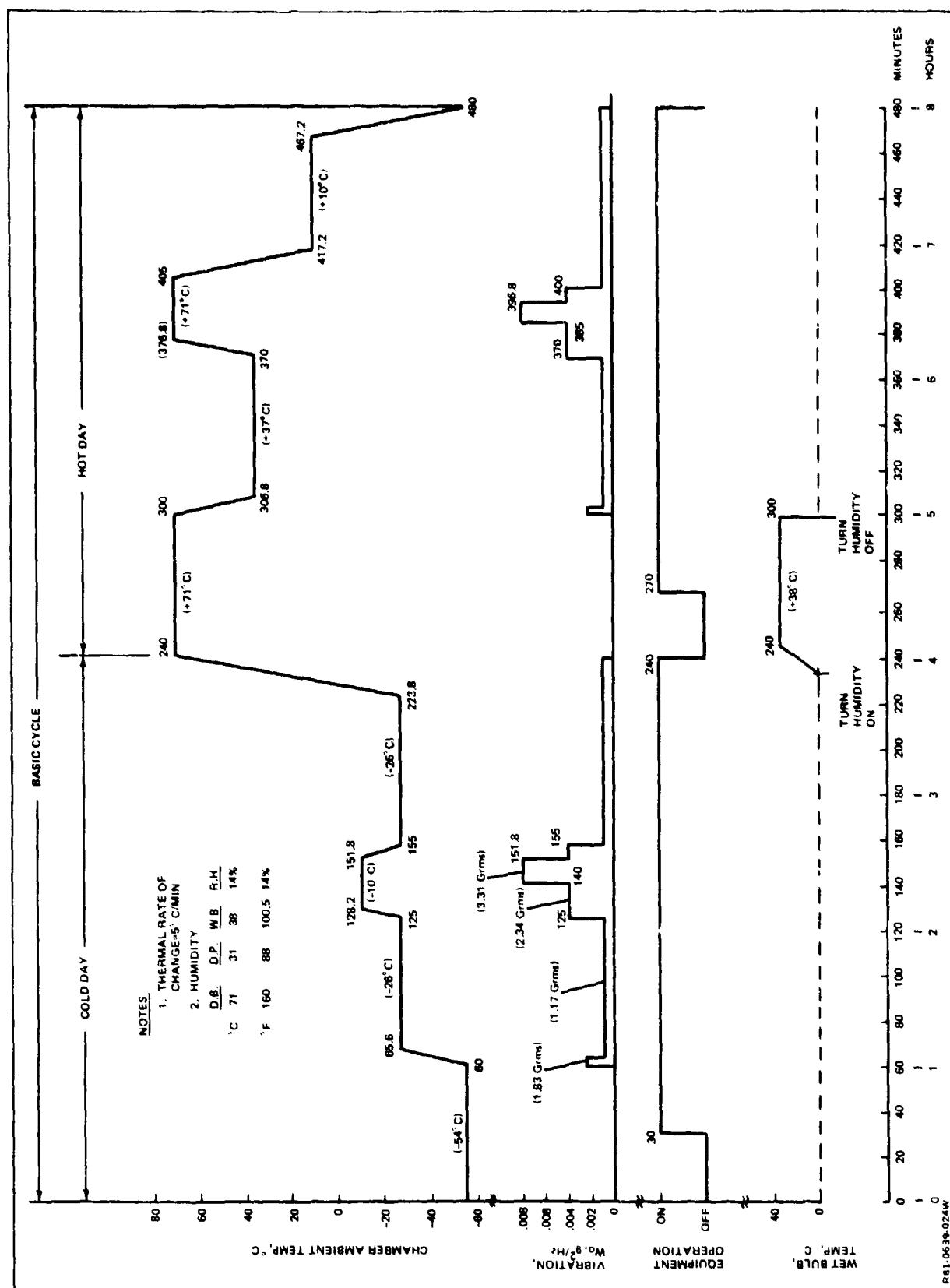


Fig. 2.2 Reliability Demonstration Test Profile

2.2 TEST SETUP AND EQUIPMENT

In order to demonstrate the operation of the two proposed methods of test control, a simulation of a reliability demonstration test on an electronic assembly was setup in the Environmental Test Lab of Grumman's Avionic Test Facility at Plant 8, Calverton, N. Y. This setup remained unchanged during the verification tests for both control methods so that their relative effectiveness could be evaluated.

2.2.1 Test Article

The test article employed in these tests was an exact mass representation of an aircraft computer. (This is the same unit used in the development of the Taped-Random Technique described in NAVMAT P-9492.) This mass representation is complete to the circuit board level, and its circuit board components have been simulated by small metallic representations bonded to the boards. All electrical connectors and major wiring bundles have been included.

The test article weighs 40 lb and measures 13" wide x 13" long x 7" high. It mounts on a flat surface using two spade lugs on the rear which slide into retainers, and two 1/4" diameter screws in a self-aligning spherical fitting in the front, designed to hold the unit in place. This type of mount is typical for replaceable electronic assemblies.

2.2.2 Electrodynamic Exciter System

All tests were performed on an MB model C-10E exciter (rated 850 lb RMS force capability - random) and an MB model T-666 Power Amplifier (rated 15 KVA). The vibration control system used in preparing the random tapes was a Hewlett-Packard model 5427A Digital Vibration Control System. *In order to insure that an over-test does not occur, the vibration system was easily modified to provide a remote over-test dump capability by wiring a "normally - closed" dump relay into the power amplifier exciter overheat circuit.* This new dump circuit requires that the operator manually reset the system to "operate" by turning the amplifier gain control to off and then back on again.

2.2.3 Environmental Test Chamber

The test chamber used in the program was a Thermotron Temperature-Humidity Chamber, Model F-15-CHMV-075-LN₂-S. It has an interior working space of 30" x 30" x 30". The chamber floor is open, with a "built-in" rubberized shroud to permit an exciter head to extend into the chamber for combined vibration-temperature testing. Primary cooling for the chamber is provided by external liquid nitrogen bottles which are valved through the chamber heat exchanger and exhausted into the test facility.

The control and instrumentation for the chamber consists of a Bristol Model TH-2T1X500FFFS4-1A two-channel pen recorder and "free-vane" controller connected to a Bristol Model TH-2S3A1X500 two channel program controller (Cam Type). Each channel is tied to a bulb-type temperature sensor located within the chamber, in the output airflow from the chamber's heat exchanger. One of the sensing bulbs is covered with a muslin sock kept moist by a small water trough to measure wet-bulb temperature for humidity measurement and control.

A modification to the chamber was made to permit remote filling and draining of the chamber humidity water system. This was required to prevent freezing of the water lines during cold portions of the temperature cycle. Three solenoid-operated water valves were installed in the chamber water supply system. A normally-closed valve was installed in the water feedline, and two normally-open valves in the drain line of the wet-bulb water trough and the humidifier water pan. This permitted filling and draining of the system with one switch circuit.

Interfacing the chamber control system with an external programmer/control was accomplished by providing eight leads to a connector at the side of the chamber control console. These eight leads provided parallel switching capability for the seven switching functions required for remote operation:

- (1) Chamber air circulator
- (2) Humidity water supply
- (3) Cam drive motor (for cam programming)

- | | | | |
|-----|---------------------------|---|------------------------|
| (4) | Air heater | } | for remote programming |
| (5) | Air cooler | | |
| (6) | Water heater-humidifier | | |
| (7) | Water cooler-dehumidifier | | |

A schematic of the chamber interface is shown in Figure 2-3. This wiring method had the advantage of permitting normal as well as remote control of the chamber without wiring changes. Remote operation only required that the manual switches on the chamber console be left open for the functions to be controlled remotely.

2.2.4 Test Setup

The test article was installed on a flat plate fixture which was bolted to the electrodynamic exciter head using a Kimbal Model 5030-3 head expander. The test chamber was then lowered over the electrodynamic exciter head until the bottom of the test article was six inches above the chamber floor. The chamber's rubber shroud was clamped around the circumference of the head expander to seal the chamber. A six inch semi-rigid foam floor was installed around the head expander to reduce heat loss through the floor of the chamber.

A 110 VAC pilot light was installed in the test article to simulate power applied to the unit as required during phases of the reliability demonstration test. Cooling air to the unit was simulated with a 110 VAC external blower adjacent to the chamber. The air duct was not connected to the test article and no system monitoring cables were connected. Figure 2-4 shows the complete setup.

2.2.5 Sine Transfer Characteristics

The initial phase of the test program was to measure the sine transfer characteristics of the system in order to synthesize and record the required random Reliability Demonstration test tapes. Three 1-g sine sweeps were made from 2000 to 15 Hz in the manner specified in NAVMAT P-9492 with the exception that the data was stored and processed directly by the H/P 5427A Digital Vibration Control System.

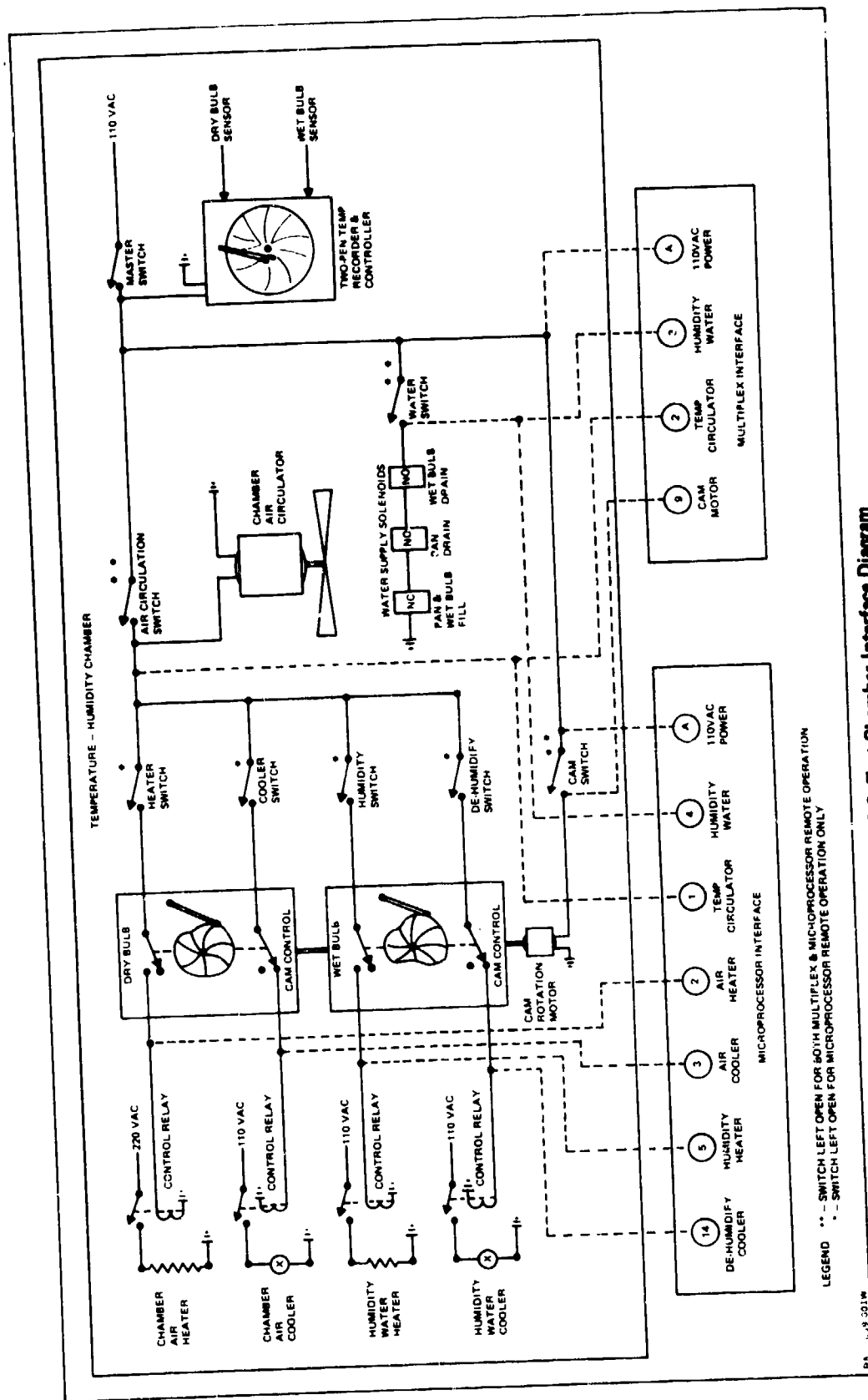


Fig. 2-3 Test Chamber Interface Diagram



Fig. 2-4 Test Setup

A sine sweep was made at room temperature, at -54°C and at $+71^{\circ}\text{C}$ to cover the test range of the thermal program. Figure 2-5, 2-6 and 2-7 are plots of the recorded sine transfer functions (E/g). The most significant differences occur at the 170 Hz test article tie-down resonance. This peak shifts to 147 Hz at -54° and 178 Hz at 71°C . Figure 2-8 shows an expanded low-frequency plot of the transfer function at these two temperature extremes.

In order to evolve a single transfer function for synthesizing the random voltages, a temperature-compensated sine transfer function was computed by averaging the functions measured in the -54°C run with those of the $+71^{\circ}\text{C}$ test run. This averaged function was successfully used to synthesize random voltages for both test methods as described in subsequent paragraphs.

A 3-g sine sweep was made at room temperature to check the linearity of the system. The data showed a shift in the tie-down resonance to 155 Hz. Since this shift was encompassed by the low-temperature shift, no linearity correction was made. [No linearity correction is needed at -54°C since only the low-level 1.83 G rms is applied. See Figure 2-2.]

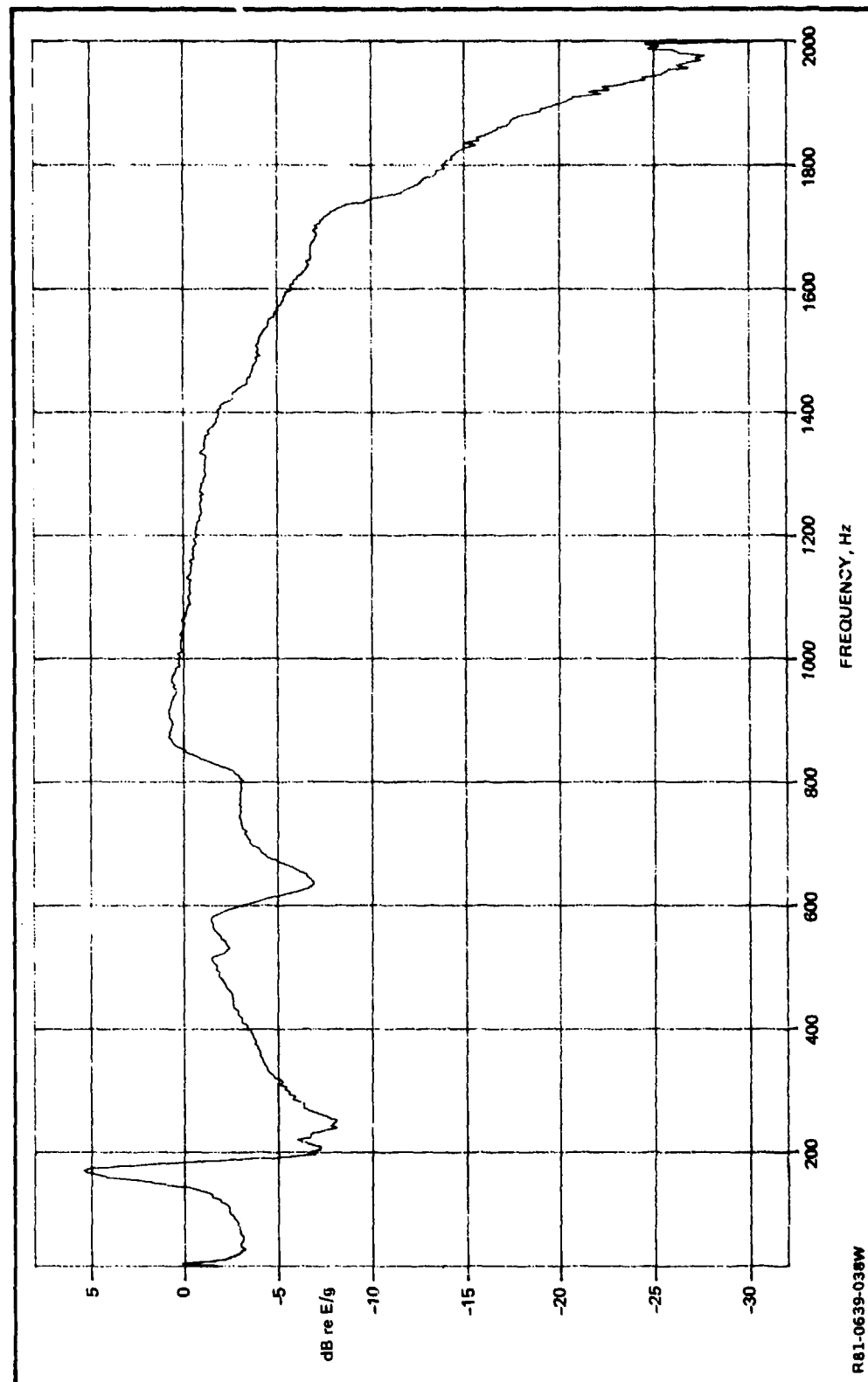


Fig. 2-5 Sine Transfer Characteristics E/G, Measured at Room Temperature

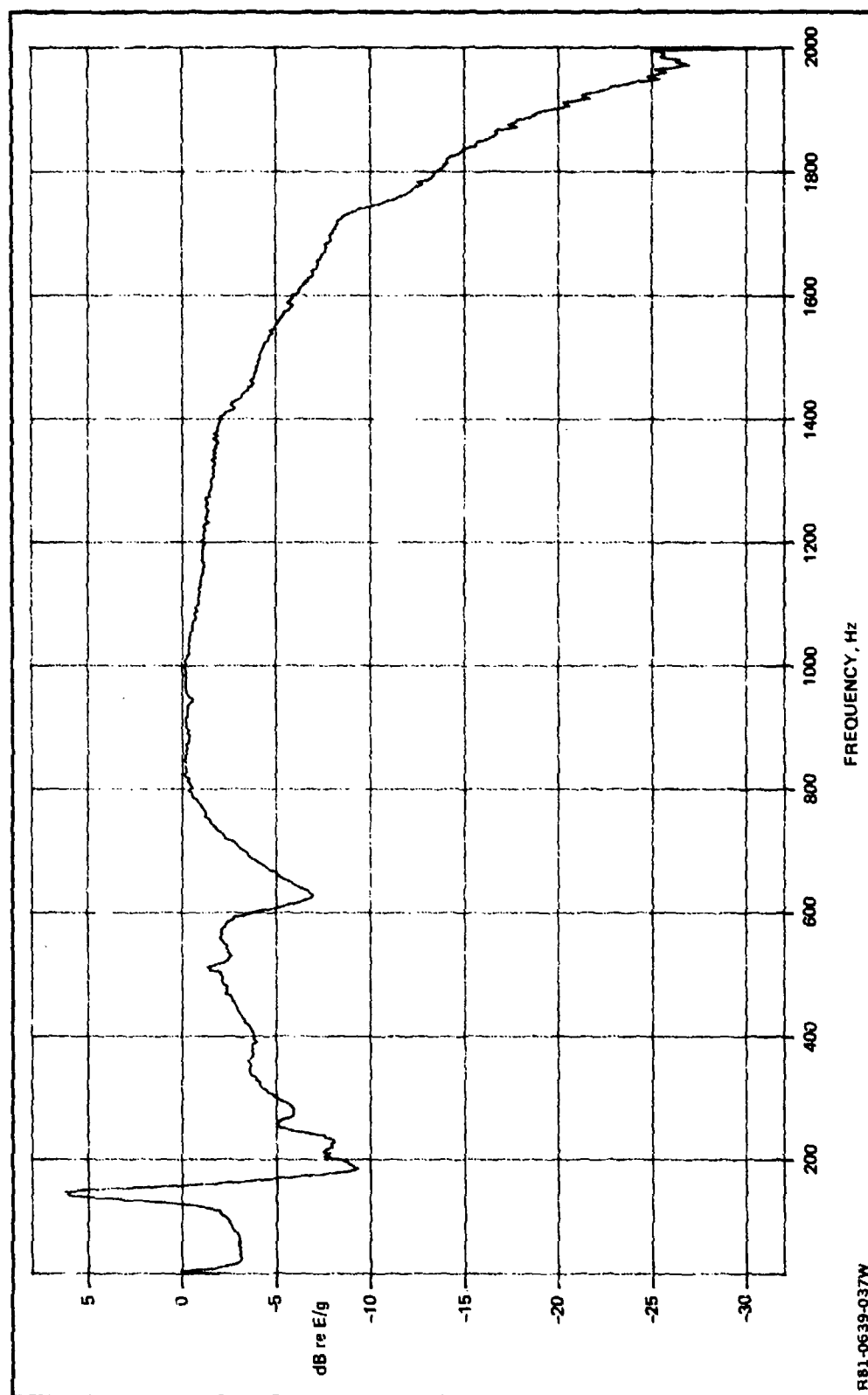


Fig. 2-6 Sine Transfer Characteristics E/G, Measured at -54°C

R81-0639-037W

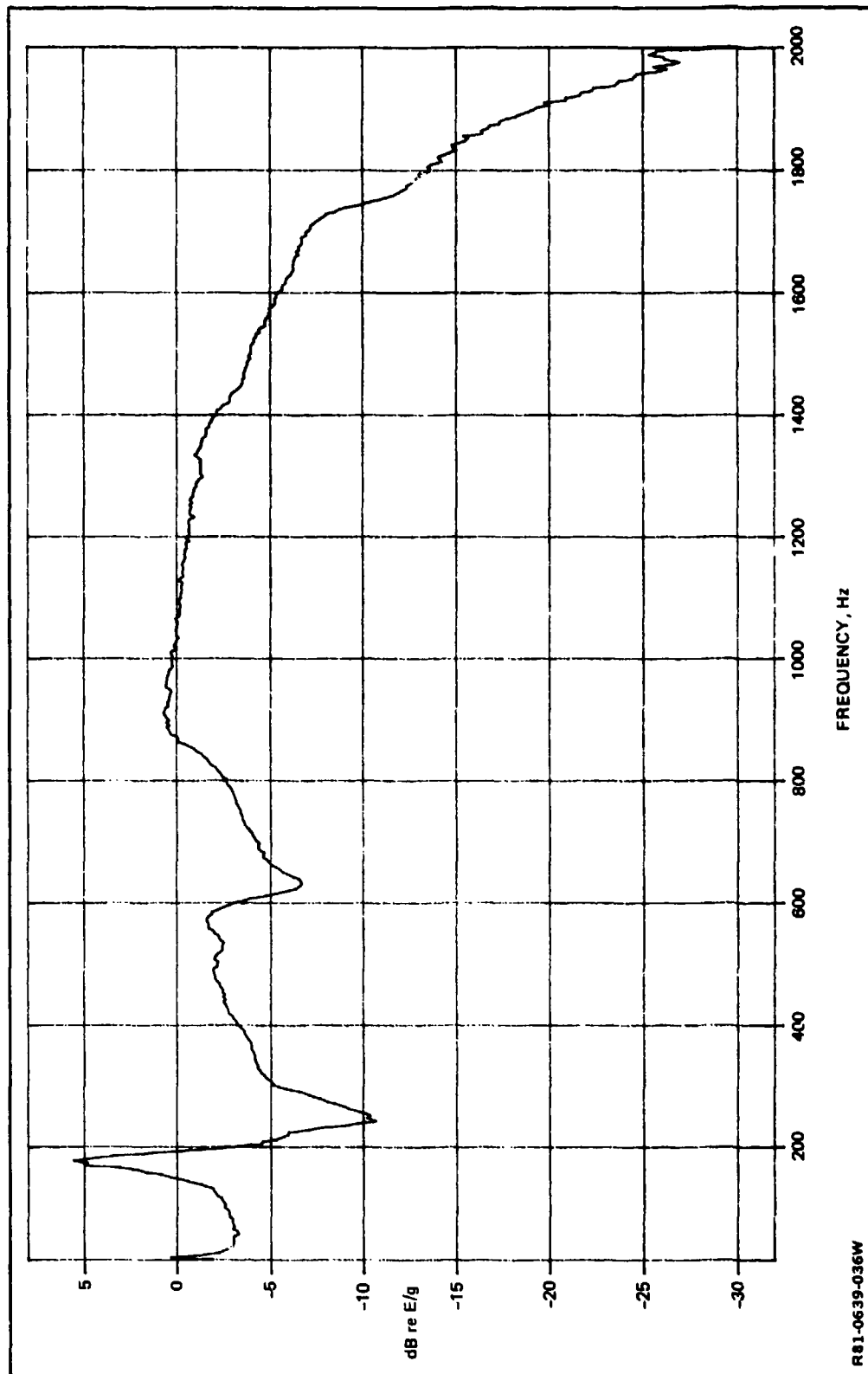


Fig. 2-7 Sine Transfer Characteristics E/G, Measured at +71°C

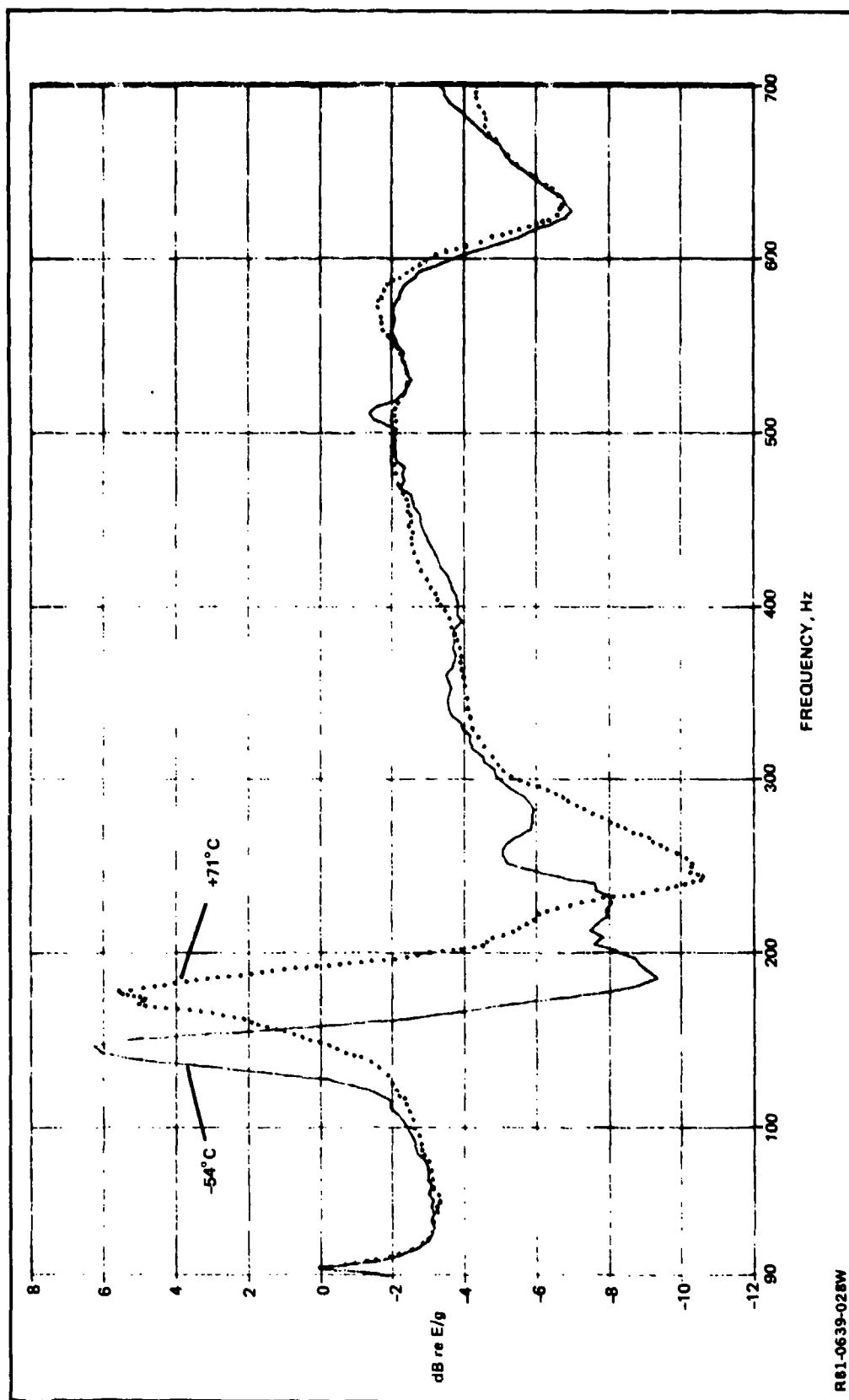


Fig. 2-8 Effect of Temperature on Sine Transfer Characteristics E/G

R61-0639-02BW

2.3 MULTIPLEX SYSTEM

The objective of the Multiplex System was to provide an inexpensive programmed controller that would interface with laboratory vibration and environmental equipment. It was intended to function with a reel-to-reel tape recorder and incorporate the necessary electronics to activate the various environmental equipment input signals.

The system described here meets all of the study requirements. It is described in detail in the following paragraphs.

2.3.1 Approach

The Multiplex System was conceived as a three-part system: (1) a technique for placing control signals on an audio tape recorder, (2) the recorder, and, (3) a technique for extracting the control signals. The final step would also include the hardware necessary to convert the control signal to an equipment ON/OFF function.

Since the environments to be controlled include vibration, temperature and humidity, and the technique is in accordance with NAVMAT P-9492, the unused (right) channel on the tape was used to convey the control signals. Although the NAVMAT procedure was followed, a standard cassette recorder was not adequate for the long-term testing anticipated. Also, since multiple control signals were necessary, a single hand-tuneable oscillator was not adequate, thus requiring the development of a tape programmer. Finally, the conversion of control signal to output function would be handled by the multiplex mainframe. This unit would contain the filters necessary to extract the control signal from the tape and convert them to a switch closure appearing at the terminal strips on the mainframe rear panel (see Figure 2-9). The use of switch closures as the only control requires suitable test equipment, i.e., cam-driven chamber, exciter amplifier levels preset, etc. All test equipment must be in a state of readiness awaiting only turn-on.

2.3.2 Tape Deck Evaluation

Unfortunately, the requirements for long-term testing negate the use of a standard cassette recorder as called for in NAVMAT P-9492. Therefore a

reel-to-reel stereo tape recorder was selected as a potential replacement. A review of manufacturers' catalogs was conducted in order to determine if a suitable recorder was on the market.

Several unique characteristics were required of the recorder, specifically:

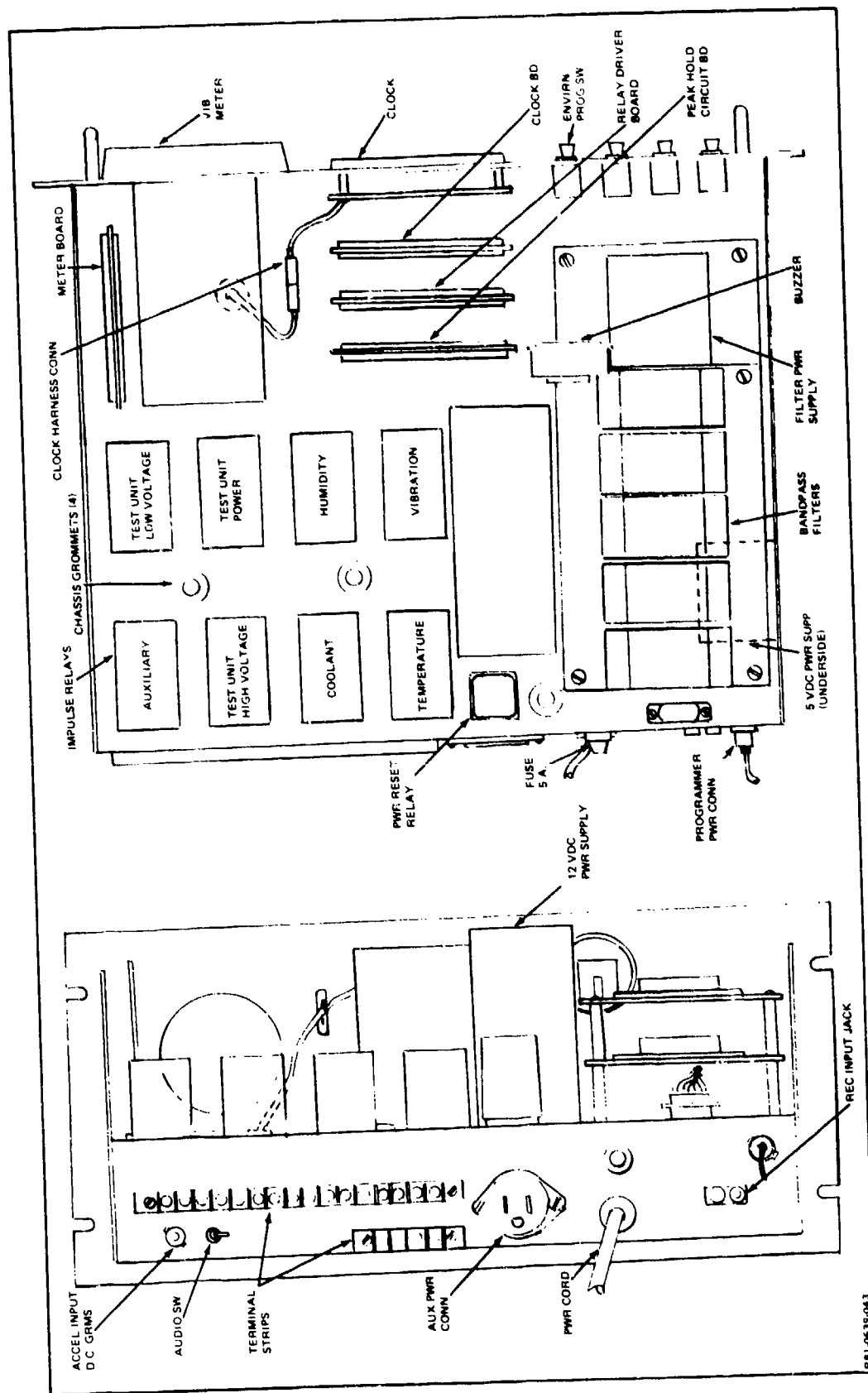
- 1) Playback of approximately eight hours,
- 2) Sound-on-sound recording, i.e., each channel may be recorded separately,
- 3) Frequency response ± 3 dB from 20 to 2000 Hz.

The reel-to-reel recorder finally selected was a Pioneer RT909 which is capable, with 1.0 mil tape, of playback in excess of four hours in both directions with automatic and continuous playback. Also, the recorder contained the sound-on-sound recording capability which permits separate recording of the vibration spectrum and control signals. Finally the recorder was subjected to a frequency response verification. The response of the unit to input levels from + 3 dB to -40 dB was recorded and plotted. The average response curve, presented in Figure 2-10, shows that the recorder satisfies the ± 3 dB requirement.

2.3.3 System Design

After selecting the reel-to-reel recorder, it was decided to use an audio oscillator as the control signal source. Since audio oscillators are generally available and familiar to laboratory personnel, various sinusoidal signals would be recorded for control signals. The environmental test equipment to be controlled would each be assigned a unique frequency, (see Table 2-3). The appearance of a control signal would either turn the equipment "on" or "off", depending upon its previous state of operation.

Recording of the oscillator signals would coincide with the environmental test time profile and be synchronized to both the temperature chamber cam controller and pre-recorded vibration spectrum on the left channel of the tape. The use of a single oscillator, although adequate, does not facilitate recording multiple signals in a very short timespan. Adjustment to each frequency, verifying the output level, and finally recording for 2-3 seconds, would be too time consuming. Therefore, a tape programmer was fabricated. It is a bank of pre-tuned,



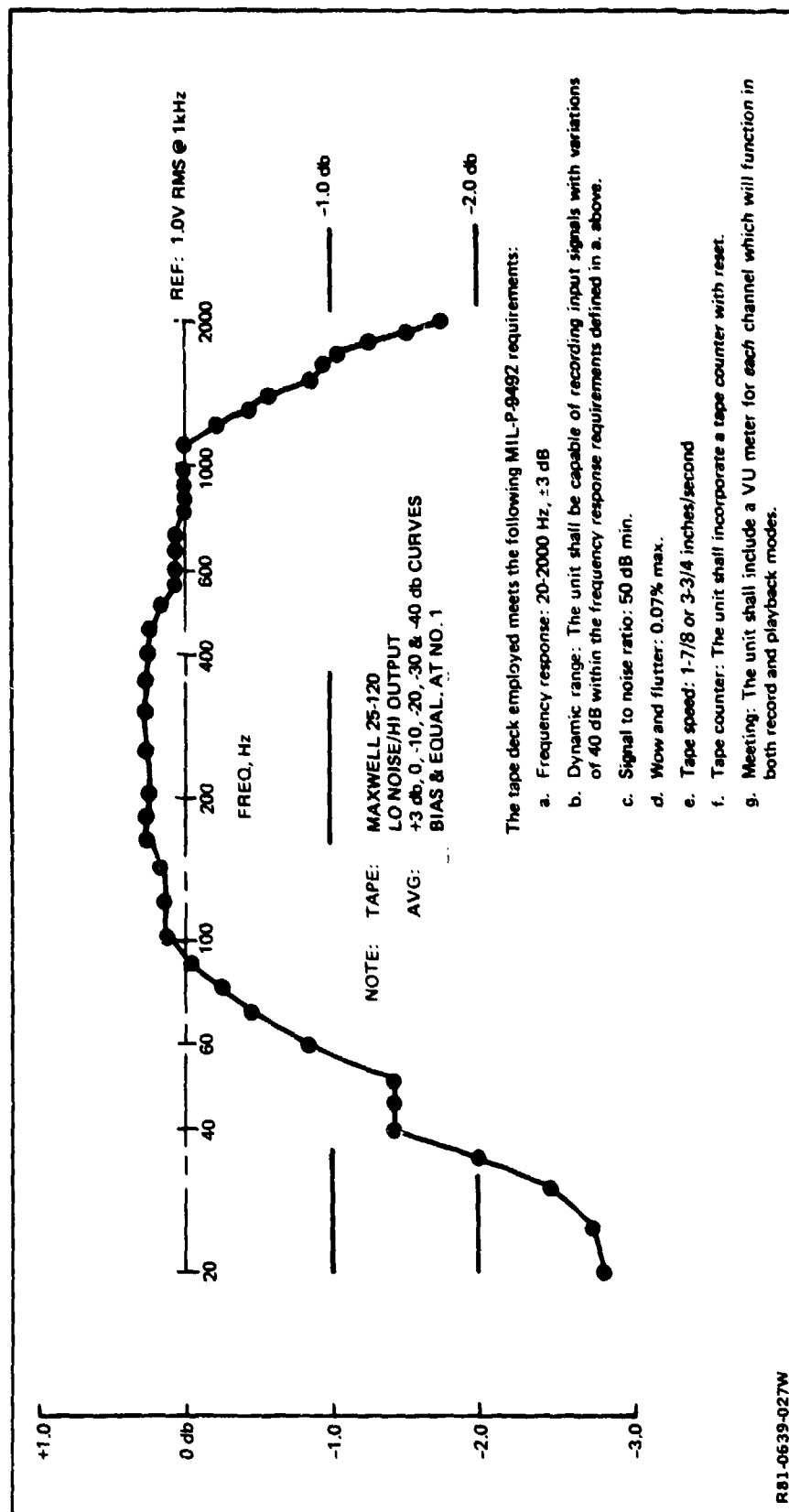


Fig. 2-10 Average Frequency Response Curve for Pioneer RT 909 Tape Deck

Table 2-3 Frequency Allocation

FREQUENCY	APPLICATION	OPERATION	OUTPUT TERMINALS
3000 HZ	VIBRATION	ON/OFF	1A & 1B
4000 HZ	TEMPERATURE	ON/OFF	2A & 2B
5000 HZ	HUMIDITY	ON/OFF	3A & 3B
6000 HZ	COOLANT	ON/OFF	4A & 4B
7000 HZ	POWER	ON/OFF	5A & 5B
8000 HZ	PWR - HIGH	ON/OFF	6A & 6B
9000 HZ	PWR - LOW	ON/OFF	7A & 7B
10,000 HZ	AUXILIARY	ON/OFF	8A & 8B
11,000 HZ	TAPE RUNNING RELAY	ON/OFF	N/A
R81-0639-047W			

pre-adjusted oscillators with independent power switches. Application of power to each oscillator provides the correct sinusoidal signal at both the front and back output connectors.

Extraction of the pre-recorded control signals would be handled through a bank of pre-tuned bandpass filters and then finally converted to an output switch closure. The Multiplex Mainframe (see Fig. 2-9) would provide the filters, power supplies, output relays and, finally, output switch closures appearing on its rear panel in the form of barrier strips. Each environment would be assigned a pair of terminals (see Table 2-3). The environmental test equipment to be controlled would be brought to a state of readiness by only requiring an ON/OFF signal. The equipment ON/OFF switch would then be parallel wired to the rear of the multiplex mainframe. The mainframe would also include all the other peripheral circuits and displays necessary to provide test time, acceleration levels, over-test alarms, etc. An overview of the circuits included in the mainframe is given in the block diagram of Figure 2-11.

2.3.3.1 Input Power Circuit - The input power circuit is shown in Figure 2-12. The circuit consists of the input fuse (5A SloBlo), reset relay, ON/OFF/RESET switch, power ON indicator, and three internal DC power supplies. The reset relay was added to cover the contingency that, should primary power be interrupted, the mainframe would not resume operation automatically upon power resumption. The circuit also includes an auxiliary power connector for the tape recorder, also wired to the reset relay and the tape programmer (+ 12 VDC) via a five-pin connector at the rear of the panel. The three internal power supplies include the ± 15 VDC bandpass filter supply, +5 VDC test clock supply, and +12 VDC relay and indicator power supply. Also tapped off the +12 VDC supply is a variable power resistor adjusted to provide +5 VDC to the relay drivers. Finally, the circuit also includes the 115V, 60Hz power to the acceleration meter and relay which are mounted on the front panel of the multiplex mainframe.

2.3.3.2 Control Circuit - The extraction of the sinusoidal control signals, within the multiplex mainframe, and its final conversion to an output switch closure, is accomplished through the control circuits. A typical circuit is presented schematically in Figure 2-13. The circuit includes four individual small circuits:

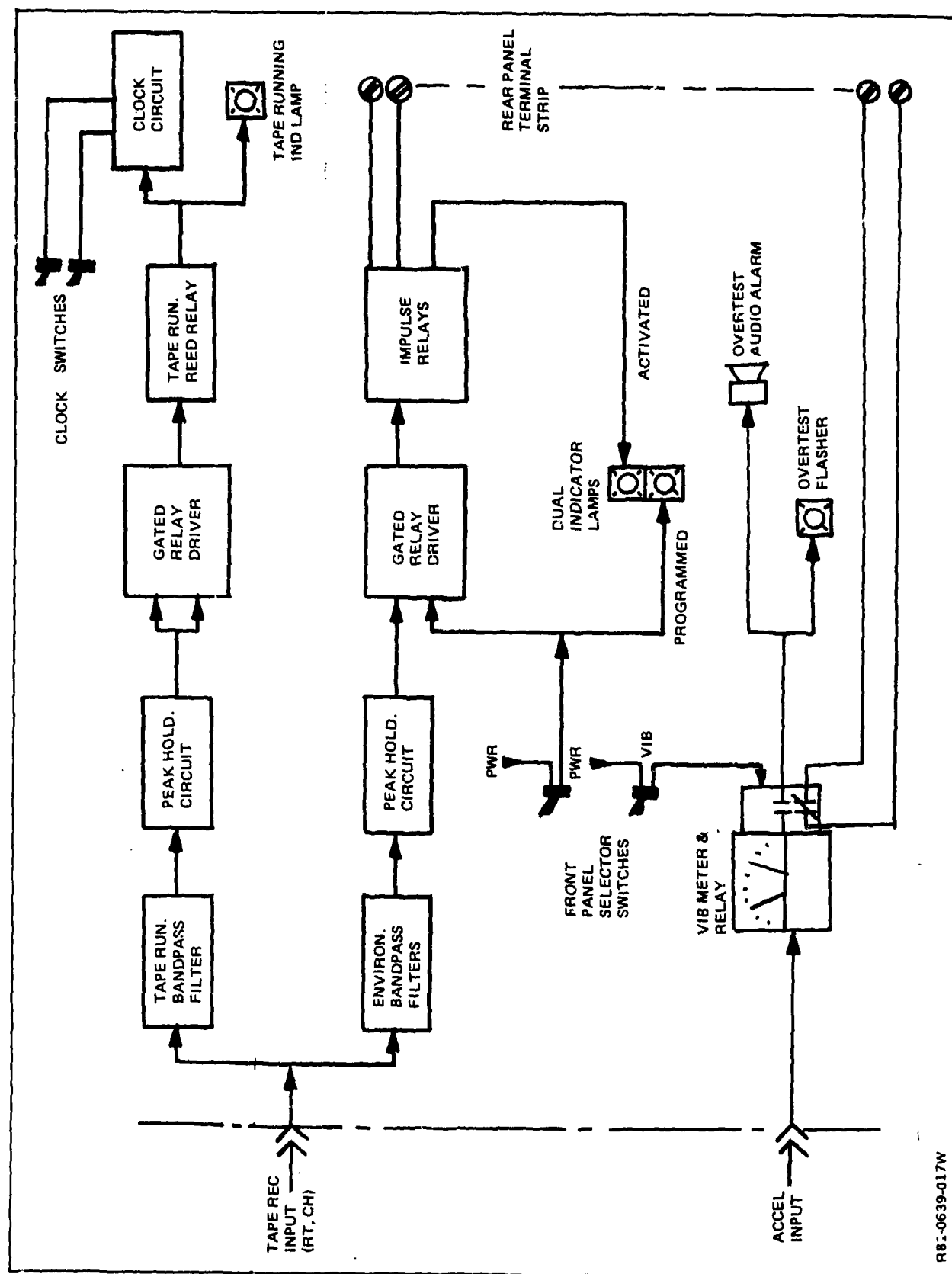


Fig 2-11 Multiplex System Block Diagram

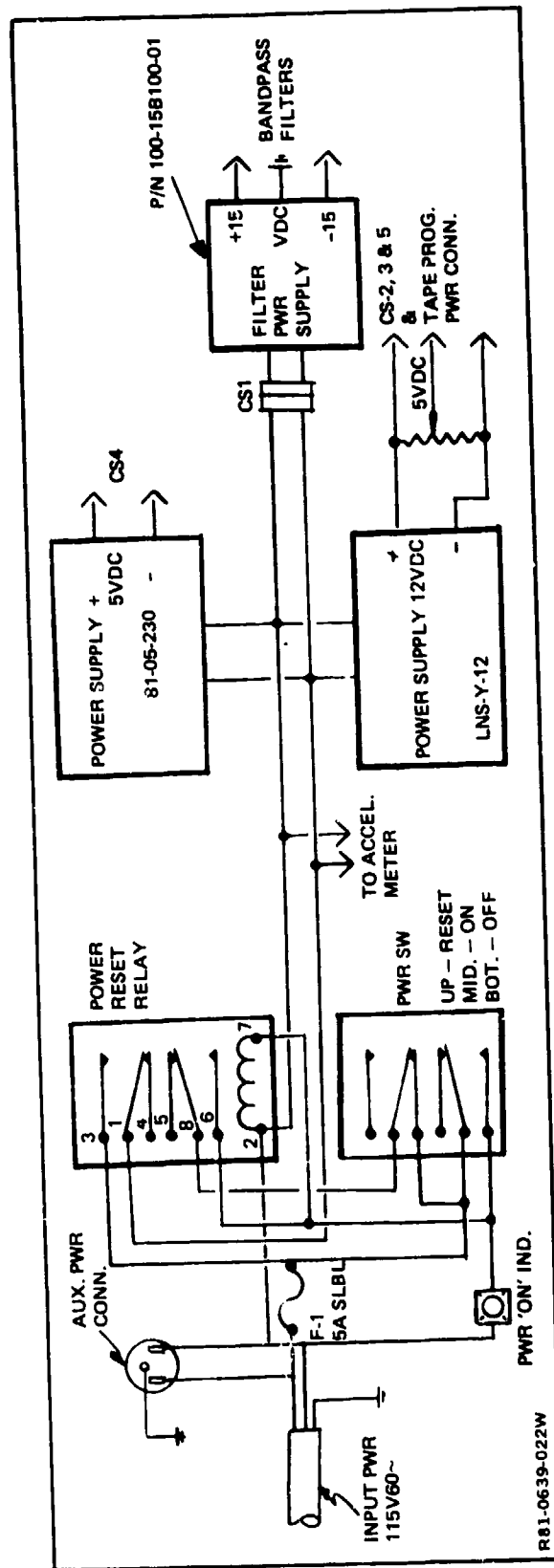


Fig. 2-12 Input Power Circuit

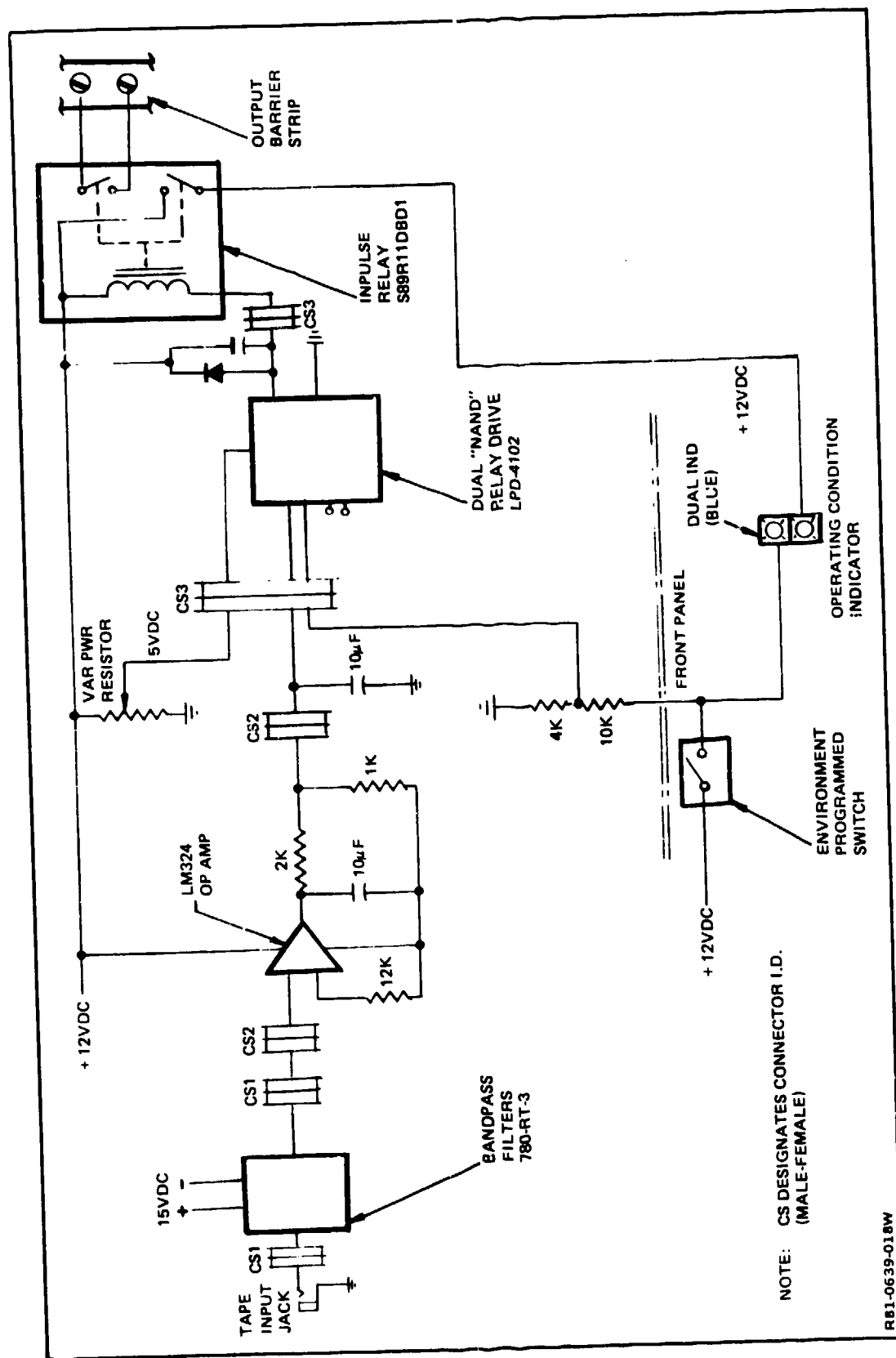


Fig. 2-13 Typical Control Circuit

the frequency discrimination, peak holding, relay driver, relay circuit and tape running circuits.

FREQUENCY DISCRIMINATION - The incoming tape signal is routed through the rear-mounted input jack and then to chassis connector CS1 (see Table 2-4). The signal is then fed in parallel to all nine bandpass filters, each tuned to frequencies from 3 kHz to 11 kHz, in 1-kHz increments. The filters are tuned with three externally-mounted resistors, per the manufacturers direction, each resistor tuned both to the center frequency (f_c) and the Q . The circuit boards containing the filters also mount a ± 15 VDC regulated power supply used exclusively for the filters.

The first eight filters are used to extract the control signals from 3 kHz to 10 kHz, the last filter is tuned to 11 kHz. This 11-kHz signal represents the "tape running signal" and is recorded throughout the entire tape programming procedure. The control signals are then superimposed upon the 11-kHz signal. The tape running signal is used to initiate the test clock and to synchronize the temperature chamber cam drive.

PEAK HOLDING - The output signal of each bandpass filter is routed through connectors CS1 and CS2 to their individual peak holding circuit. The circuit consists of an operational amplifier configured so that its output charges a 10 μ f capacitor to approximately 3 VDC. Since the recorded control signal (other than the 11 kHz) appears only briefly, the capacitor is charged only upon appearance of the control signal. Removal of the signal causes the capacitor to discharge. The low-level signal output of the peak holding circuit represents one-half of the logic signal required by the relay drivers.

RELAY DRIVER/RELAY CIRCUITS - The relay drivers are dual input "NAND" gated 2.0 Ampere power drivers. There are two drivers per TO-3 package and five are required to support the sine output signals. The first four drivers receive their input signals one each from the peak holding circuit and the other from the multiplexer mainframe front panel environmental program switches. The programming switch provides +12 VDC across a voltage divider, the output of which is passed through connector CS3 to the "B" side of each driver input. The

Table 2-4 Connector Pin Designations

PIN	CS-1	PIN	CS-2	PIN	CS-3	PIN	CS-5
1	FILTER NO. 1 OUTPUT	1	INPUT OP AMP NO. 1A LM 324*	1	CONTROL SIG INPUT-DRIVER NO. 1A	18	OUTPUT BLINKER CIRCUIT, FR PANEL IND.
2	FILTER NO. 2 OUTPUT	2	INPUT OP AMP NO. 1B	2	CONTROL SIG INPUT-DRIVER NO. 1B	E	N.C. CONTACT-ACCEL METER
3	FILTER NO. 3 OUTPUT	3	INPUT OP AMP NO. 1C	3	CONTROL SIG INPUT-DRIVER NO. 2A	F	ACCEL INPUT-CH AMP D.C. OUTPUT
4	FILTER NO. 4 OUTPUT	4	INPUT OP AMP NO. 1D	4	CONTROL SIG INPUT-DRIVER NO. 2B	H	OUTPUT TO METER INPUT
5	FILTER NO. 5 OUTPUT	5	INPUT OP AMP NO. 11A	5	CONTROL SIG INPUT-DRIVER NO. 3A	J	TO BAR. STRIP TERM. 10B
6	FILTER NO. 6 OUTPUT	6	INPUT OP AMP NO. 11B	6	CONTROL SIG INPUT-DRIVER NO. 3B	K	TO BAR. STRIP TERM. 10A
7	FILTER NO. 7 OUTPUT	7	INPUT OP AMP NO. 11C	7	CONTROL SIG INPUT-DRIVER NO. 4A	L	TO BAR. STRIP TERM. 9B
8	FILTER NO. 8 OUTPUT	8	INPUT OP AMP NO. 11D	8	CONTROL SIG INPUT-DRIVER NO. 4B	N	TO BAR. STRIP TERM. 9A
9	FILTER NO. 9 OUTPUT	9	INPUT OP AMP NO. 11B	9	CONTROL SIG INPUT-DRIVER NO. 5A	S	INPUT 12VDC-OVERTEST IND RESET
11	INPUT SIG. GND	11	OUTPUT OP AMP 1A	11	FRONT PANEL SWX INPUT-DRIVER NO. 1A	T	N.O. CONTACT-ACCEL METER
12	INPUT SIG.	12	OUTPUT OP AMP 1B	12	FRONT PANEL SWX INPUT-DRIVER NO. 1B	U	TEMP CAM RELAY GND
14	115V 60~	13	OUTPUT OP AMP 1C	13	FRONT PANEL SWX INPUT-DRIVER NO. 2A	V	+12VDC
15	115V 60~	14	OUTPUT OP AMP 1D	14	FRONT PANEL SWX INPUT-DRIVER NO. 2B	Y	12VDC GND
		15	OUTPUT OP AMP 11A	15	FRONT PANEL SWX INPUT-DRIVER NO. 3A		
		16	OUTPUT OP AMP 11B	16	FRONT PANEL SWX INPUT-DRIVER NO. 3B		
		17	OUTPUT OP AMP 11C	17	FRONT PANEL SWX INPUT-DRIVER NO. 4A		
		18	OUTPUT OP AMP 11D	18	FRONT PANEL SWX INPUT-DRIVER NO. 4B		
		19	OUTPUT OP AMP 11B				
		Y	12VDC GND	21	OUTPUT DRIVER NO. 1A, BAR. STRIP TERM. 1		
		Z	+12VDC	22	OUTPUT DRIVER NO. 1B, BAR. STRIP TERM. 2		
			*I.C. - QUAD OP AMPS	A	OUTPUT DRIVER NO. 2A, BAR. STRIP TERM. 3		
				B	OUTPUT DRIVER NO. 2B, BAR. STRIP TERM. 4		
				C	OUTPUT DRIVER NO. 3A, BAR. STRIP TERM. 5		
				D	OUTPUT DRIVER NO. 3B, BAR. STRIP TERM. 6		
				E	OUTPUT DRIVER NO. 4A, BAR. STRIP TERM. 7		
				F	OUTPUT DRIVER NO. 4B, BAR. STRIP TERM. 8		
				J	OUTPUT DRIVER NO. 5A TO PIN W CS-4		
				M	+12 VDC-VOLT. DIVIDER INPUT DRIVER NO. 5B		
				X	+5VDC FROM VARIABLE PWR RES-DRIVER PWR		
				Y	12VDC GND		

R81-0639-02SW

"A" input is furnished through CS3 as well. The relay driver input power, + 5 VDC, is derived from a variable power resistor placed on the output of the + 12 VDC regulated supply (see Figure 2-12).

The presence of both logic signals (A&B) at the input of each driver causes the output to go to ground. The impulse relays used for each environment are powered directly with + 12 VDC, from the regulated supply. Only the return side of the relay is connected to the driver output. When the driver is activated, the relay return is shorted directly to ground through the driver. The addition of a diode and capacitor across the relay coils is necessary to suppress over-voltage switching transients and ringing during turnoff.

Impulse relays were selected as the output media because these units only change state when a pulse of input voltage is applied. Therefore, continuous power is not required to hold relays in a particular position. Each relay contains two microswitches, rated at 15 amps. One of the switches is wired directly to the output barrier strip on the rear panel of the mainframe. The second switch has + 12 VDC applied and is wired directly to the lower lamp of the operating condition indicators on the mainframe front panel (see Figure 2-14). The indicator then displays the operating state of each impulse relay. The upper half of the indicator is on whenever the program switch is activated (see Figure 2-14).

TAPE RUNNING CIRCUIT - The circuit, although similar to the other control circuits (see Figure 2-11) up to the relay driver, differs in that, instead of using a impulse relay, it supplies the return path for two reed relays. The first relay is located on the clock circuit board and is wired in such a manner that, whenever the tape recorder is running, the relay is activated and initiates the clock display. The second relay appears on the meter control board (see Figure 2-15) and is designated R3. The contacts of this relay (K3) are located in the cam control circuit, barrier strip terminals 9A and 9B. Closure of the normally-open contacts provides the gate current necessary to trigger the control TRIAC (RS-1000). Therefore the cam will only advance when the tape is running, assuring synchronization of tape and cam. Also included is a front panel lamp (green) which, when lighted, indicates that the electrical tape running signal is present.

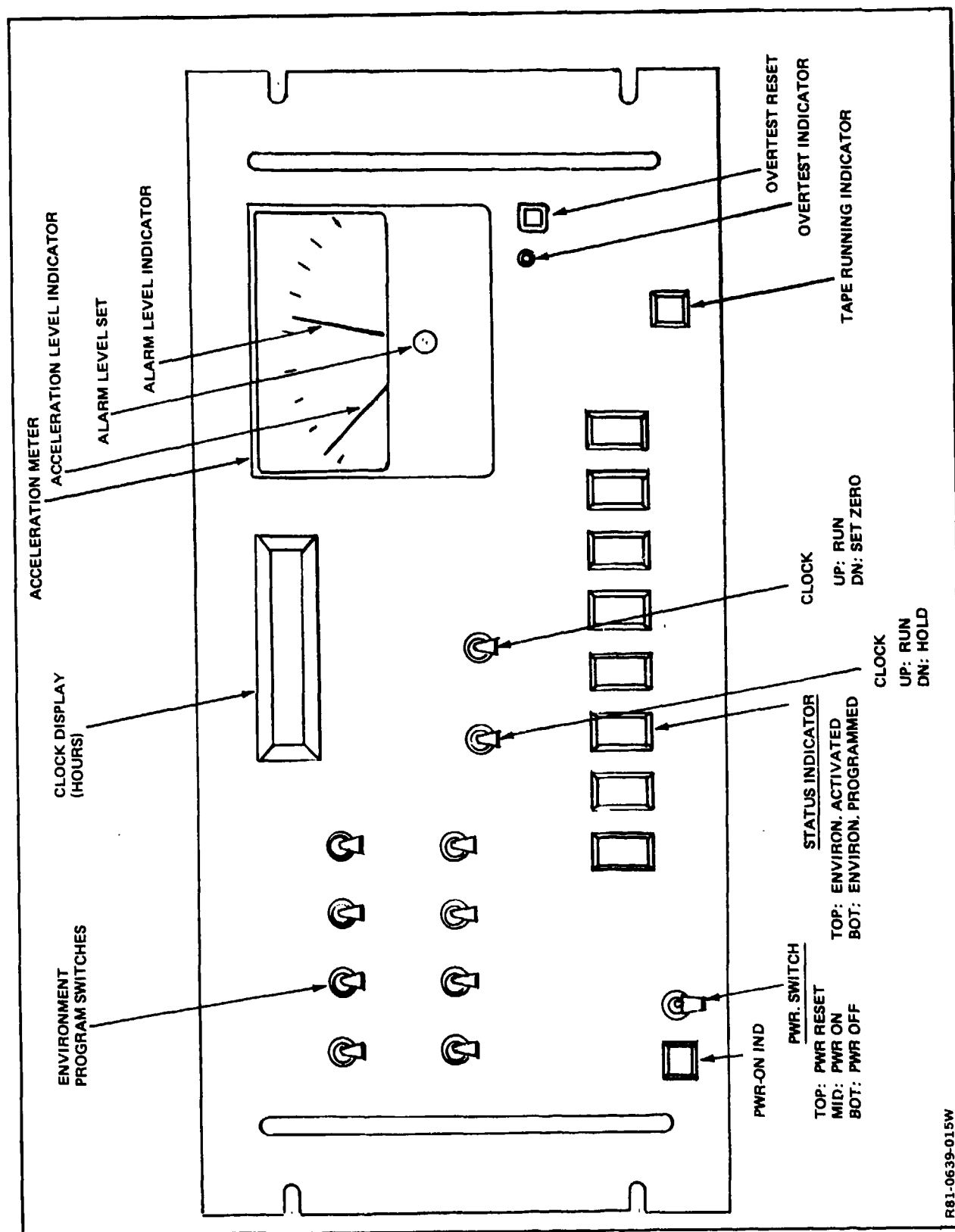


Fig. 2-14 Multiplex Front Panel

R81-0639-015W

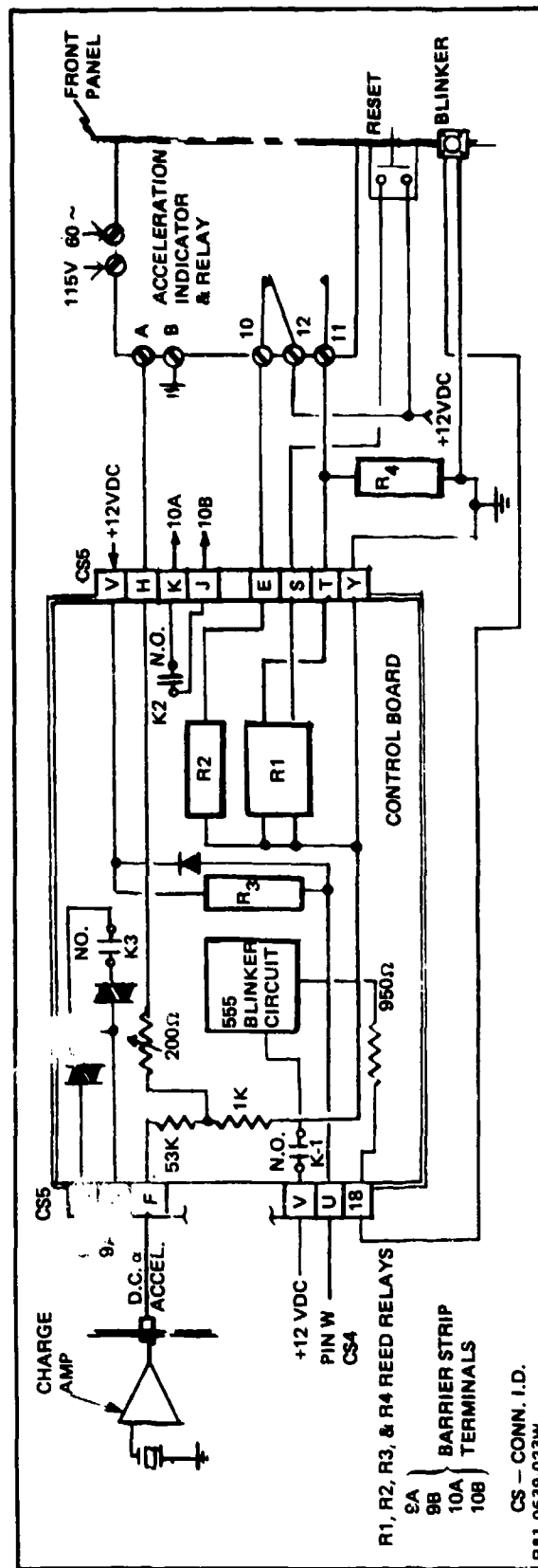


Fig. 2-15 Meter and Control Circuits

2.3.3.3 Clock Circuits - The clock circuits include the clock circuit board, display board with interconnecting harness, and mainframe front panel control switches. These components are presented in Figure 2-16, and the interconnection between boards is listed in Table 2-17.

CLOCK CIRCUIT BOARD - This board contains sixteen integrated circuit (IC) components, along with the tape running relay. Power to the board is furnished by the +5VDC regulated power supply shown in Figure 2-12. This supply is dedicated to the clock circuits. The first IC (#1) is a crystal-controlled oscillator with an output of 9.6 MHZ. IC No. 2 through 10 divide the 9.6 MHZ downward until the final output of No. 10 is 0.02777 HZ, or a period of 36 seconds. This 36-second period represents 0.01 hours, or the lowest increment of time the clock will count. The upper limit is 9999.99 hours. IC No. 11 through 16 are decade counters, each driving a display IC. The clock circuit is volatile, i.e., loss of primary power will cause the clock to cease functioning, restoration of power requires restart of the clock from 0000.00 hours.

DISPLAY BOARD AND INTERCONNECTING HARNESS - The display board contains ICs 17 through 22, which are numeric displays with logic. These six ICs and their circuit board are installed directly on the mainframe front panel. The display board is connected to the clock circuit board with a single harness, which contains a pair of mating connectors. The addition of these connectors permits removal of the display board from the front panel for bench testing.

FRONT PANEL CONTROL SWITCHES - The clock circuit and display are controlled using the two leftmost switches, mounted on the front panel directly under the clock display. The first switch, designated RUN/HOLD, controls the oscillator output to the next (No. 2) IC. In the RUN position (up), the oscillator output is fed directly into the next IC. The down position interrupts this function, causing the clock to display the last time increment. The RUN/ZERO switch must also be in the run position for the clock to function. Placing the switch in the zero position causes the clock to display zero time. The functions of these switches are further restricted by the Tape Running Relay. The relay must be actuated or the switches have no effect.

2.3.3.4 Peripheral Circuits and Displays - This portion of the Multiplex Mainframe circuitry contains the acceleration meter/relay alarm circuits and cam control circuit. The acceleration input to the mainframe is furnished separately as the DC output of the Control Accelerometer Charge Amplifier. The description of the charge amplifier circuitry is limited to the requirement that its output be a DC voltage proportional to acceleration levels.

ACCELERATION METER/RELAY - The meter selected to display the acceleration level is a 0-10mVDC meter with an integral upper limit settable relay. A DC meter was selected to take advantage of its inherent clamping characteristics and the range was selected as a convenience. The rear portion of the meter contains input signal terminals, relay contact terminals and input power terminals for 115V 60Hz.

The relay upper limit set point is established with a knob located on the meter front panel. The set point determines the point at which the relay operates. The relay contains a set of both normally-open and -closed contacts.

The input signal to the meter first passes through the control board (Figure 2-15) via the CS5 connector. A voltage regulator is used to proportion the input to the meter's range. A small potentiometer is provided for fine adjustment. During normal operation, below the relay set point, the +12VDC supplied to the pole (terminal No. 12) of the relay holds reed relay R2 activated. The contacts (K2) of relay R2 are normally open and are wired to the barrier strip terminals 10A and B. During normal operation these contacts are closed; during an overtest, the contacts open and the shaker is shutdown automatically.

ALARM CIRCUITS - There are two alarm circuits, one visual and one audible. Both are actuated when the meter set-point is exceeded. The "Blinker Circuit" on the control board (Figure 2-15) is the visual indicator that the set-point has been passed.

The circuit contains a 555 timer IC, several resistors and one capacitor. Components were selected to cause the LED mounted under the meter on the Mainframe Front Panel, to "blink" once per second. Reed Relay R1, controlled by the meter, in turn controls the power to the blinker circuit through its contact K1. Once activated, the LED will continue to "blink" until reset by pushing

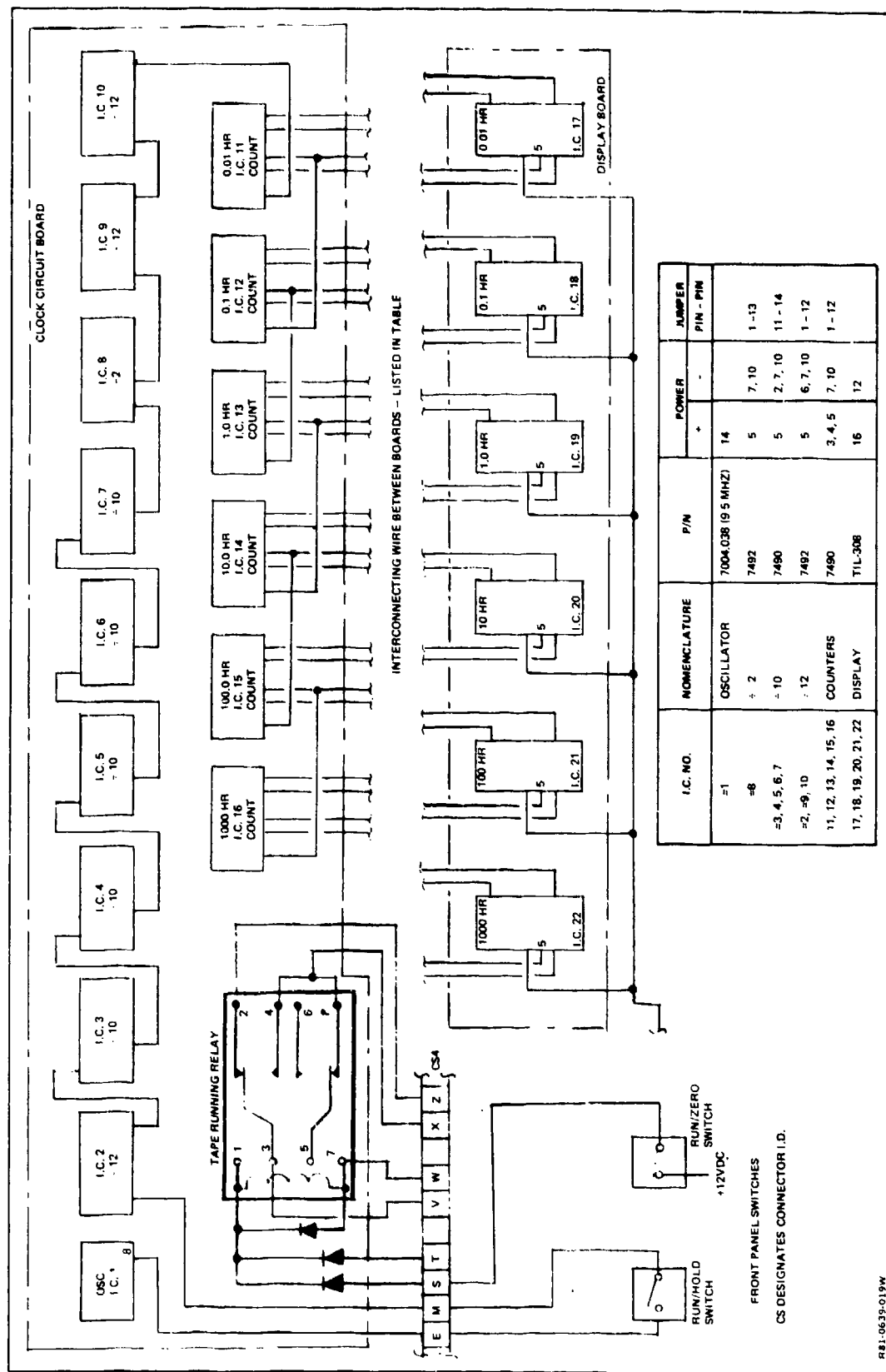


Fig. 2-16 Clock Circuits

- FROM -		- TO -
CLOCK CIRCUIT BD.	CONN CS4	
I.C. NO. 11 PIN 12	1	(A) 0.01 HR DISPLAY I.C. PIN 15
I.C. NO. 11 PIN 9	2	(Y) 0.01 HR DISPLAY I.C. PIN 10
I.C. NO. 11 PIN 8	3	(B) 0.01 HR DISPLAY I.C. PIN 6
I.C. NO. 11 PIN 11	4	(N) 0.01 HR DISPLAY I.C. PIN 7
I.C. NO. 12 PIN 12	6	(X) 0.10 HR DISPLAY I.C. PIN 15
I.C. NO. 12 PIN 9	7	(M) 0.10 HR DISPLAY I.C. PIN 10
I.C. NO. 12 PIN 8	8	(Z) 0.10 HR DISPLAY I.C. PIN 6
I.C. NO. 12 PIN 11	9	(C) 0.10 HR DISPLAY I.C. PIN 7
I.C. NO. 13 PIN 12	11	(P) 1.0 HR DISPLAY I.C. PIN 15
I.C. NO. 13 PIN 9	12	(D) 1.0 HR DISPLAY I.C. PIN 10
I.C. NO. 13 PIN 8	13	(S) 1.0 HR DISPLAY I.C. PIN 6
I.C. NO. 13 PIN 11	14	(b) 1.0 HR DISPLAY I.C. PIN 7
I.C. NO. 14 PIN 12	16	(T) 10.0 HR DISPLAY I.C. PIN 15
I.C. NO. 14 PIN 9	17	(H) 10.0 HR DISPLAY I.C. PIN 10
I.C. NO. 14 PIN 8	18	(V) 10.0 HR DISPLAY I.C. PIN 6
I.C. NO. 14 PIN 11	19	(e) 10.0 HR DISPLAY I.C. PIN 7
I.C. NO. 15 PIN 12	A	(K) 100 HR DISPLAY I.C. PIN 15
I.C. NO. 15 PIN 9	B	(d) 100 HR DISPLAY I.C. PIN 10
I.C. NO. 15 PIN 8	C	(U) 100 HR DISPLAY I.C. PIN 6
I.C. NO. 15 PIN 11	D	(J) 100 HR DISPLAY I.C. PIN 7
OSCILLATOR OUTPUT	E	FRONT PANEL SWX CLOCK "START"
I.C. NO. 16 PIN 12	F	(f) 1000 HR DISPLAY I.C. PIN 15
I.C. NO. 16 PIN 9	H	(L) 1000 HR DISPLAY I.C. PIN 10
I.C. NO. 16 PIN 8	J	(h) 1000 HR DISPLAY I.C. PIN 6
I.C. NO. 16 PIN 11	K	(W) 1000 HR DISPLAY I.C. PIN 7
I.C. NO. 2 PIN 14	M	FRONT PANEL SWX CLOCK RUN/HOLD
PIN 2 I.C.s, 11, 12, 13, 14, 15, 16	N	FRONT PANEL SWX CLOCK RUN/ZERO
TAPE RUN. RELAY PIN 1	S	+12VDC
TAPE RUN. RELAY PIN 1	T	NOT CONNECTED
TAPE RUN. RELAY PIN 3	V	(E) +5VDC POWER DISPLAY I.C.s PIN 16
TAPE RUN. RELAY PIN 7	W	(R) PIN 5 DISPLAY I.C.s (ALL)
TAPE RUN. RELAY PINS 4 & 8	X	TO CS3 PIN J AND CS5 PIN U
NOT CONNECTED	Y	5VDC GND
TAPE RUN. RELAY PIN 2	Z	12VDC GND
		+5VDC SUPPLY
		(c) PIN 12 ON DISPLAY I.C. (ALL)

() - DESIGNATES CLOCK HARNESS CONNECTOR PINS

R81-0639-026W

Fig. 2-17 Clock Circuit Connector Wiring

the reset button located on the front panel. Reset is also accomplished through Relay R1 which is a dual reed relay.

The audio alarm also functions through the meter. Once the set-point is exceeded, +12VDC is applied to Reed Relay R4. The contacts (K4) of R4 are located within a small circuit (Figure 2-18) located in the rear of the Mainframe Chassis. The circuit contains a nine-volt battery, buzzer and rear panel selector switch. A nine-volt battery was used to avoid electrical noise generated by the buzzer being fed back to the primary power supplies. The ON/OFF switch was also a convenience and disengages the alarm when visual observation of the meter is available.

CAM CONTROL CIRCUIT - The Cam Control Circuit contains a TRIAC, DIAC, Reed Relay (R3) and the Tape Running Relay Driver. The Cam on/off switching is accomplished through the barrier strip terminals 9A and 9B (Figure 2-9). The Tape Running Relay Driver provides the ground path for the +12 VDC supply voltage used in this control circuit. Therefore the circuit only functions when the tape is running (playing back). During playback, relay R3 is activated, closing the contacts (K3) located in the DIAC circuit. Normally the cam motor requires 115V 60Hz to operate. It is this voltage that is passed through the DIAC and turns the output TRIAC (PN RS1000) to "on". Once "on", the cam will operate so long as the tape continues to playback.

2.3.3.5 Tape Programmer - The Tape Programmer consists of nine function generators wired to operate as independently-tuned sinusoidal oscillators. The output frequencies vary from 3 kHz to 11 kHz in approximately 1 kHz increments.

FRONT PANEL - The Programmer Front Panel, Figure 2-19, contains the primary power switch and indicator, as well as individual oscillator power switches, frequency adjustment potentiometers, and output connector. The Frequency Select Switches, red toggles, control the power to each function generator. Similarly, the Tape Running Switch, white toggle, controls power to the 11 kHz generator. The frequency adjustment pot access holes are in the upper right corner of the panel. Above each switch is engraved the nominal frequency, controlled by the switch. Prior to recording, each frequency should be adjusted to within 5% of the nominal.

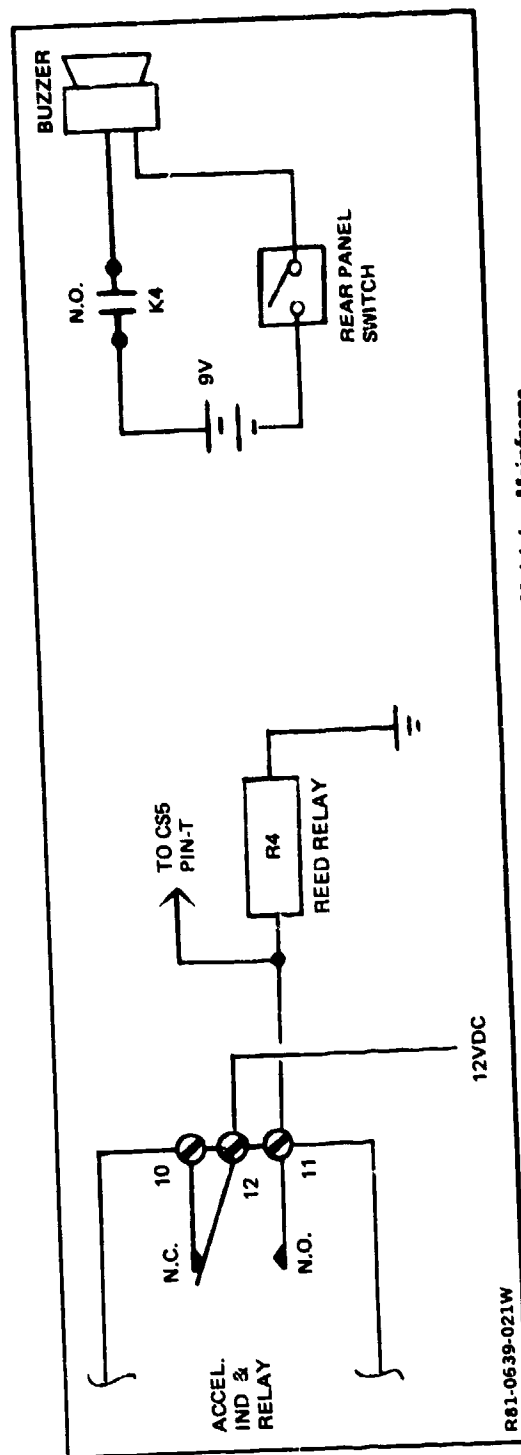


Fig. 2-18 Acceleration Overtest Audio Alarm, Multiplex Mainframe

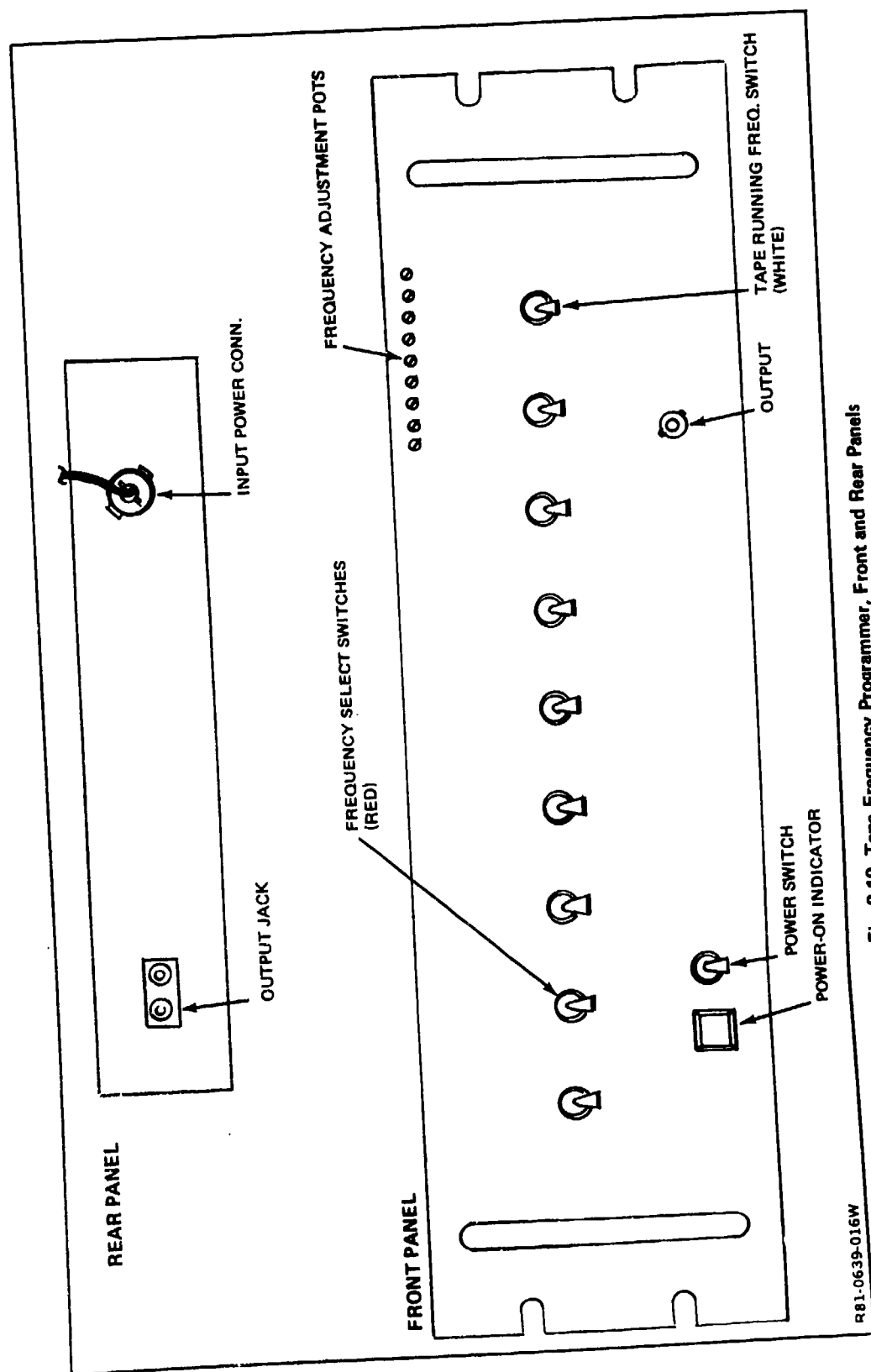


Fig. 2-19 Tape Frequency Programmer, Front and Rear Panels

OSCILLATOR CIRCUITS - A typical circuit is presented in Figure 2-20. The function generator (ICL8038CCJD) is capable of providing square wave, ramp and sinusoidal outputs. The circuits are configured for sinusoidal outputs. The generators require +12VDC for operation, and power is provided by the Multiplex Mainframe through rear panel connectors on both the mainframe and programmer. The power to the programmer is controlled by the front panel power switch although each generator has its own power switch. The outputs of all the generators are the input to a single Operational Amplifier (OpAmp). The output of the OpAmp is adjusted to approximately 0.250 Vrms using the 100K potentiometer. The variable capacitor, on the input side of the OpAmp is adjusted to minimize harmonic distortion. Output connectors appear on both the front and rear panels to facilitate setup and recording.

Figure 2-20 also contains a table of nominal frequencies for each generator. These nominal values are engraved on the front panel. The actual frequency of each generator is also presented, along with the tuning resistor value installed in each generators output.

2.3.3.6 INTERFACING - The Multiplex Mainframe interfaces with four segments of the test system:

- (1) Temperature-humidity chamber
- (2) Vibration shaker system
- (3) Tape deck
- (4) Test article support equipment

Figure 2-21 shows a block diagram of these interfaces.

For convenience the Multiplex Mainframe was combined in a single console with the tape deck and tape programmer (see Figure 2-22). External cabling was used to connect the multiplex console with the test chamber and vibration system. Test article support equipment was limited in this development program to a cooling blower and simulated test article power.

2.3.4 System Programming

As noted in the previous section, event programming information in the Multiplex System is recorded on the right channel of the tape, and the random

vibration signal is recorded on the left channel. The programming of the temperature-humidity profile must be accomplished with the chamber cam programmer.

Two independent Reliability Demonstration programs were recorded on tape. The first was the eight-hour profile discussed in Subsection 2.1, which incorporates all of the vibration, temperature, and humidity requirements in accordance with MIL-STD-781C. The second tape was made so that a short 30-minute test profile could be demonstrated. This tape has all of the required MIL-STD-781C environmental and operational functions, but for a lesser period of time.

2.3.4.1 Reliability Demonstration Test Program - Figure 2-2 graphically describes the eight-hour Reliability Demonstration test profile. To insure that the required temperature versus time profiles are controlled and repetitive, two cams were machined from .063 aluminum material for the temperature/humidity cam programmer. Figure 2-23 shows the cam profile for the dry bulb (chamber air) temperature. Figure 2-24 is the cam profile for the wet bulb (humidity) temperature. The cams are based on an eight-hour rotation period for the cam drive. (The cycle time of the program must be compatible with available gearing for the cam drive motor.) Once cut, the cams were hand filed during chamber operation to fine-tune the temperature program.

RANDOM NOISE PROGRAMMING - The random noise spectrum required for the reliability demonstration test is shown in Figure 2-1. Using the temperature-compensated sine transfer characteristics measured for the system (see para. 2.2.5) and the measured tape recorder characteristics (see para 2.3.2) a synthetic random noise spectrum was calculated for the required test spectrum. Table 2-5 presents the tabulated results of this calculation. (The derivation and application of this technique is explained in NAVMAT P-9492.) The normalized synthetic random (last column in Table 2-5) was programmed into the H/P 5427A Digital Vibration Control System.

The Reliability Demonstration program, as defined by MIL-STD-781C, requires that random vibration spectrum be applied at four different test levels at various times and for different durations during the program. This information was programmed into the H/P 5427A vibration control system. A tabulation of the H/P 5427A is shown in Table 2-6.

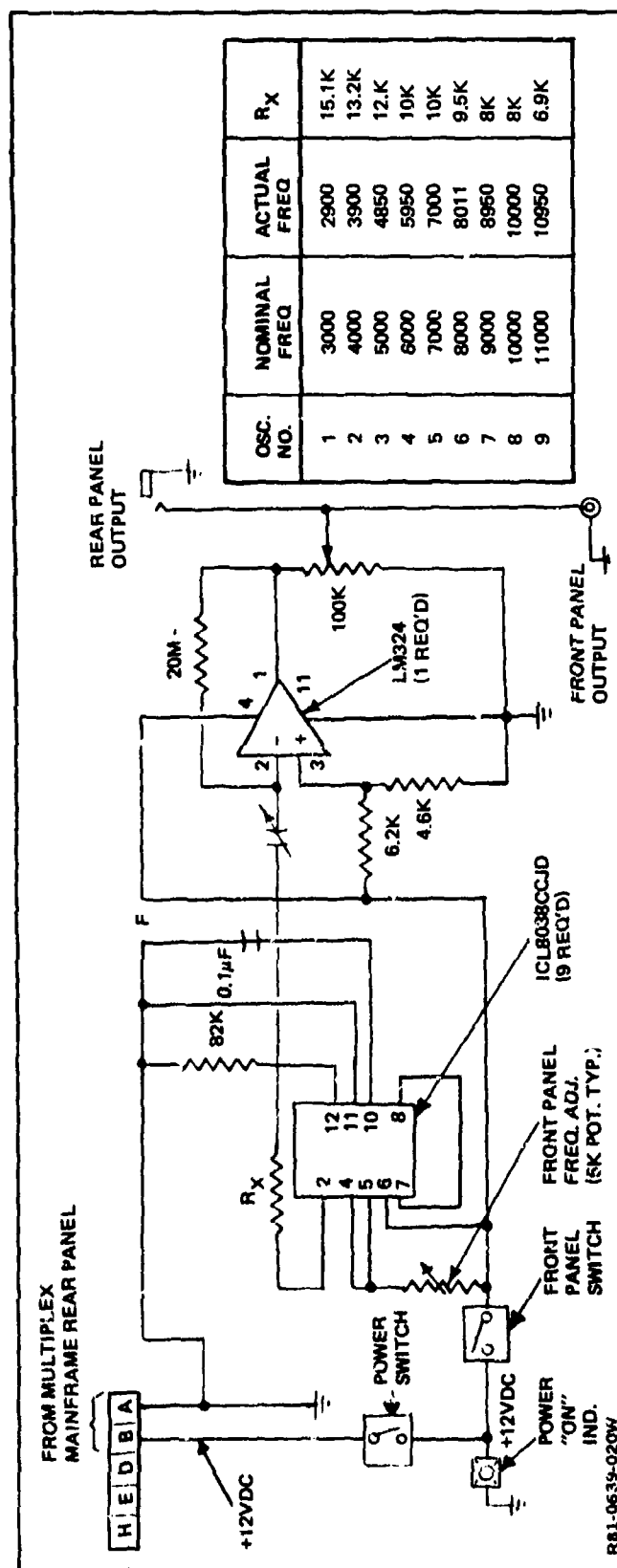


Fig. 2-20 Tape Programmer, Typical Oscillator Circuit

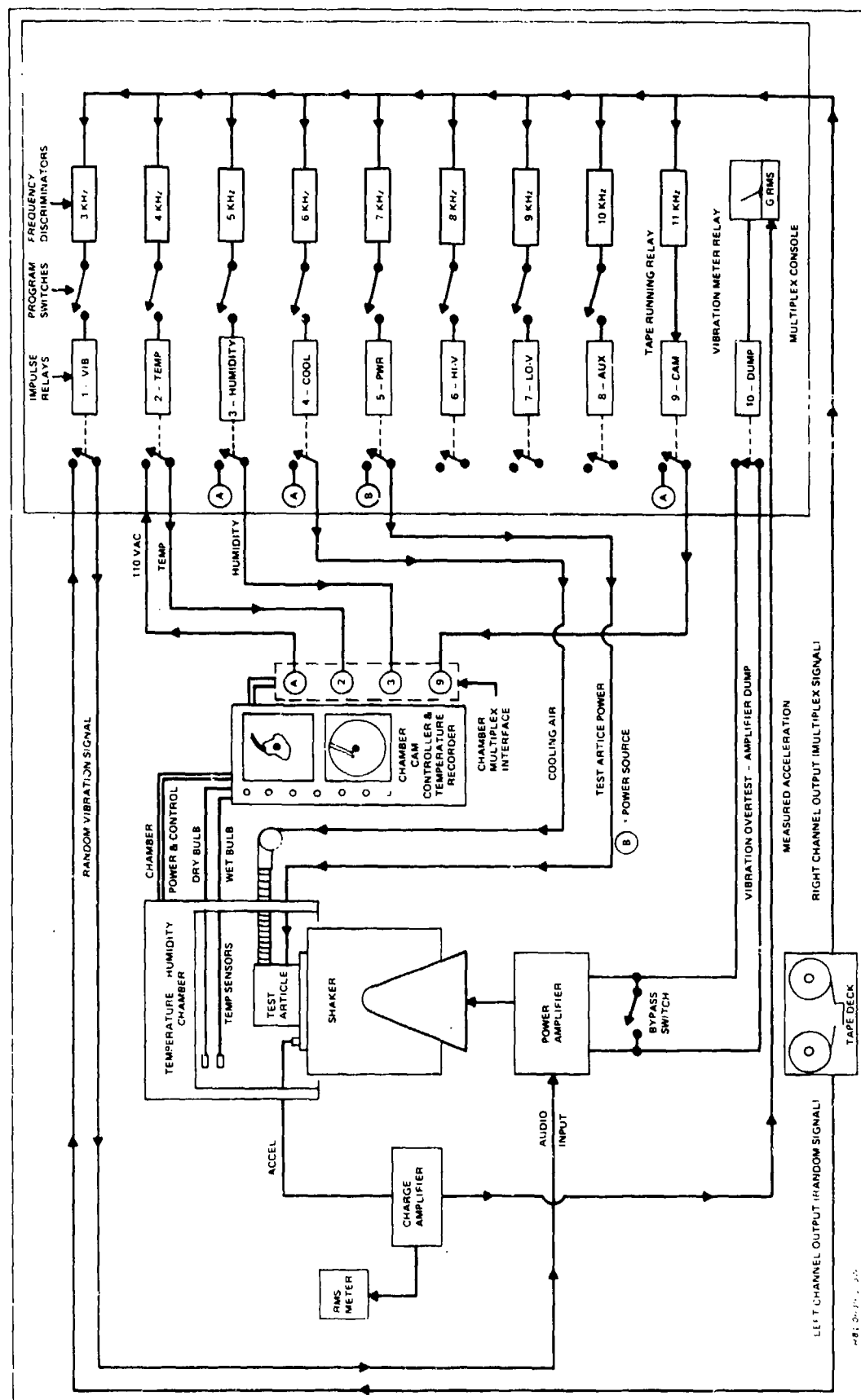
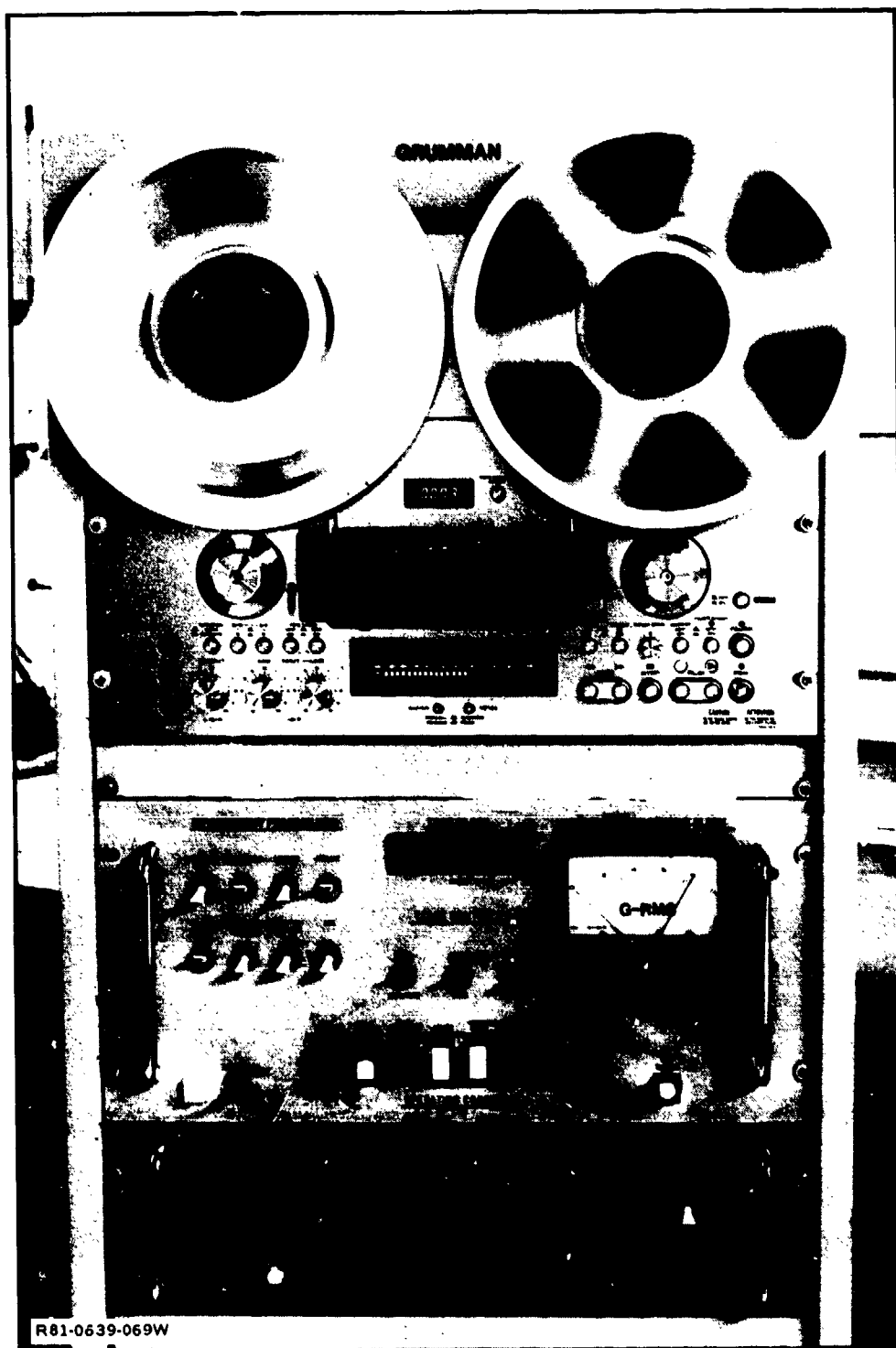
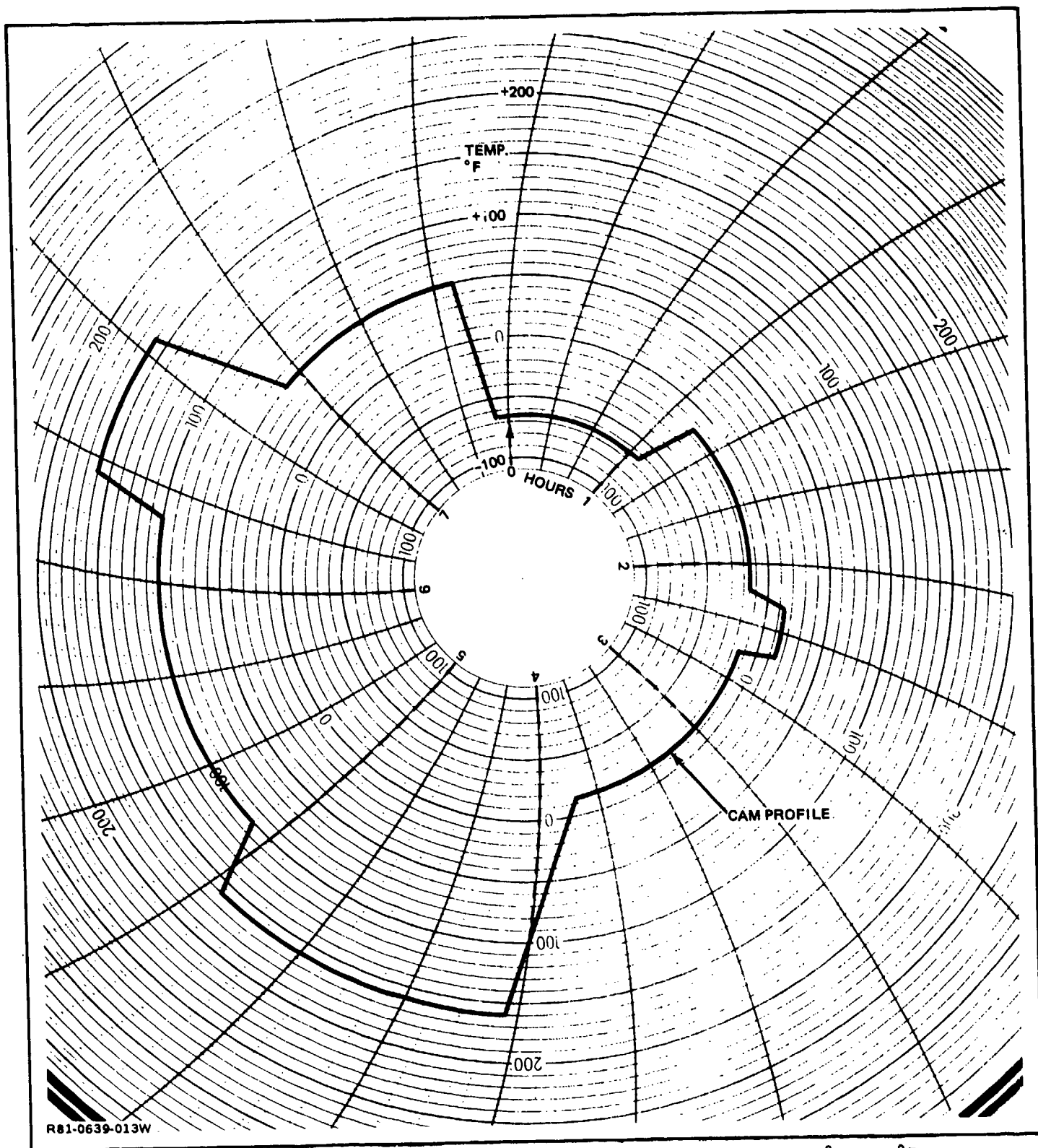


Fig. 2-21 Multiplex Test System



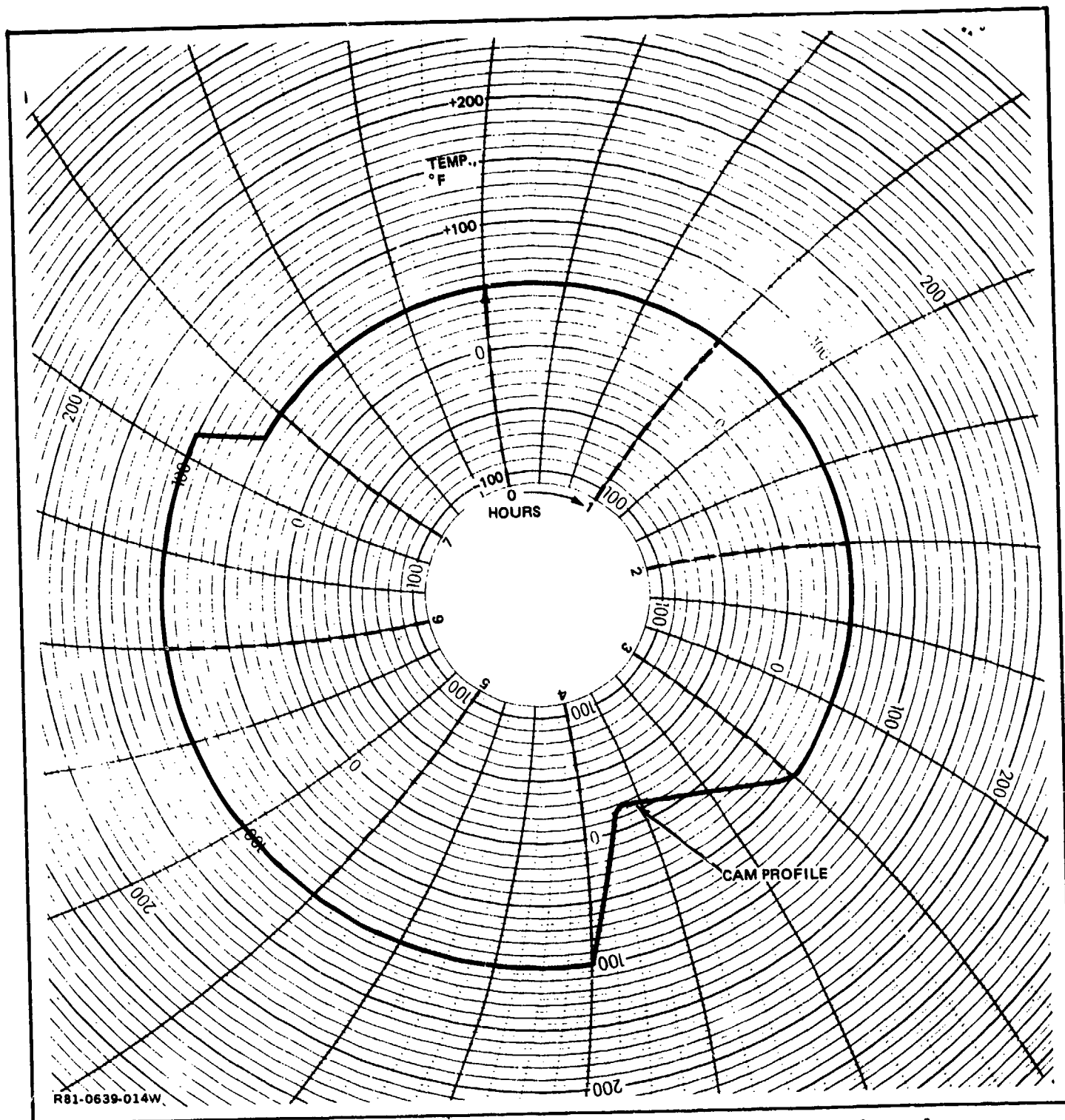
R81-0639-069W

Fig. 2-22 Multiplex System Console



R81-0639-013W

Fig. 2-23 Reliability Demonstration Profile #1, 8-hr Program, Dry Bulb Temperature: -65°F to 160°F



R81-0639-014W

Fig. 2-24 Reliability Demonstration Profile #1, 8-hr Program, Wet Bulb Temperature: +50° to 100° F

Table 2-5 Tabulation Sheets for Synthetic Random Spectrum

TITLE: MULTIPLEX SYSTEM Side										Date: 1-29-81		
TEST A: MASS MOCKUP - REL. DEMO TEST PROGRAM S/N												
Part No. Analysis with HIP 5427A										Axis Z		
SYSTEM FILTERS			SINE DATA			COMPENSATION FACTORS			CORRECT. FUNC.		SYNTHETIC RAND.	
No.	B.W. (Hz)	C.F. (Hz)	SINE DATA			Type Peak (dB)	Linear Factor (dB)	Var. Factor (dB)	Correct E/g (dB)	Req'd. g/Hz (dB)	Req'd. E/Hz (dB)	Normalized (g ² /Hz)
			(A) E/G -65°F (dB)	(B) E/G +160°F (dB)	(C) E/g AVG. (dB)							
1	10	15	31.1	31.2	31.2	+6.3			37.5	6.3	43.8	7.20
2	11	26	29.8	29.9	29.9	+2.7			32.6	6.3	38.9	2.33
3	12	37	29.4	29.5	29.5	+1.7			31.2	6.3	37.5	1.69
4	13	50	29.4	29.3	29.4	+1.4			30.8	6.3	37.1	1.54
5	14	63	29.4	29.3	29.4	+0.7			30.1	6.3	36.4	1.31
6	14	77	29.6	29.4	29.5	+0.3			29.8	6.3	36.1	1.22
7	15	92	30.0	29.6	29.8	0			29.8	6.3	36.1	1.22
8	16	107	30.3	29.9	30.1	-0.1			30.0	6.3	36.3	1.28
9	17	124	32.3	30.2	31.3	-0.1			31.2	6.3	37.5	1.69
10	18	141	37.8	31.3	34.6	-0.2			34.4	6.3	40.7	3.52
11	25	163	30.3	34.5	32.4	-0.3			32.1	6.3	38.4	2.08
12		188	23.4	34.2	28.8	-0.3			28.5	6.6	35.1	0.971
13		213	24.5	27.3	25.9	-0.3			25.6	7.5	33.1	0.613
14		238	25.1	23.0	24.1	-0.3			23.8	8.2	32.0	0.476
15		263	26.8	23.2	25.0	-0.3			24.7	8.7	33.4	0.656
16		288	26.9	25.6	26.3	-0.3			26.0	9.1	35.1	0.971
17		313	28.0	27.5	27.8	-0.3			27.5	9.3	36.8	1.44
18		338	28.6	28.0	28.3	-0.3			28.0	9.3	37.3	1.61
19		363	28.6	28.3	28.5	-0.3			28.2	9.3	37.5	1.69
20		388	28.5	28.6	28.6	-0.3			28.3	9.3	37.6	1.73
21	Y	413	28.8	29.3	29.1	-0.3			28.8	9.3	38.1	1.94
max = 43.8			let 44db = 8.0 g ² /Hz			WORKSHEET 1 of 4						
min = 10.7			then 0 db = 0.0003 g ² /Hz						3 ⁷ /Hz 0.0003 x 10 (dB)			
Δ 33.1												
R81-0639-058(1/4)W												

Table 2-5 Tabulation Sheets for Synthetic Random Spectrum (Contd)

Tape No		MULTIPLY SYSTEM		Side:		Date: 1-29-81	
Test Article		MASS MOCKUP - REL DEMO TEST PROGRAM		S N		-	
Part No		Analysis with H/P 5427A		Axis		Z	

SYSTEM FILTERS		SINE DATA			COMPENSATION FACTORS			CORRECT FUNC.		SYNTHETIC RAND.		
		(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	
No.	B.W. (Hz)	C.F. (Hz)	E/G -65°F (dB)	E/G +160°F (dB)	E/G AVG. (dB)	Tape Deck (dB)	Linear Factor (dB)	Var. Factor (dB)	Corrected E/G (dB)	Req'd. E/Hz (dB)	Normalized (g ² /Hz)	
22	25	438	29.3	29.6	29.5	-0.3			29.2	9.3	38.5	2.12
23		463	29.8	30.0	29.9	-0.2			29.7	9.3	39.0	2.38
24		488	30.1	30.2	30.2	-0.2			30.0	9.3	39.3	2.55
25		513	30.3	30.0	30.2	-0.2			30.0	9.3	39.3	2.55
26		538	30.0	30.0	30.0	-0.1			29.9	9.3	39.2	2.50
27		563	30.1	30.5	30.3	-0.1			30.2	9.3	39.5	2.67
28		588	29.2	29.7	29.5	-0.1			29.4	9.3	38.7	2.22
29		613	26.5	27.0	26.8	-0.1			26.7	9.3	36.0	1.19
30		638	26.2	26.0	26.1	-0.1			26.0	9.3	35.3	1.02
31		663	27.2	27.1	27.2	-0.1			27.1	9.3	36.4	1.31
32		688	28.5	27.7	28.1	-0.1			28.0	9.3	37.3	1.61
33		713	29.6	28.2	28.9	-0.1			28.8	9.3	38.1	1.94
34		738	30.5	28.6	29.6	0			29.6	9.3	38.9	2.33
35		763	31.1	28.9	30.0	0			30.0	9.3	39.3	2.55
36		788	31.6	29.3	30.5	0			30.5	9.3	39.8	2.87
37		813	31.8	29.9	30.9	0			30.9	9.3	40.2	3.14
38		838	32.0	30.6	30.8	0			30.8	9.3	40.1	3.07
39		863	32.0	31.9	32.0	0			32.0	9.3	41.3	4.05
40		888	31.9	32.5	32.2	0			32.2	9.3	41.5	4.24
41		913	31.9	32.8	32.4	0			32.4	9.3	41.7	4.44
42	Y	938	31.8	32.6	32.2	0			32.2	9.3	41.5	4.24

R81-0639-058(2/4)W

WORKSHEET 2 of 4

R81-0639-058(2/4)W

WORKSHEET 2 of 4

Table 2-5 Tabulation Sheets for Synthetic Random Spectrum (Contd)

Tape No. <u>MULTIPLEX SYSTEM</u> Side: <u>-</u> Date: <u>1-29-81</u>	
Test Article: <u>MASS MOCKUP-REL DEMO TEST PROGRAM</u> S/N <u>-</u>	
Part No. <u>Analysis with HIP 54271</u> Axis <u>Z</u>	

SYSTEM FILTERS			SINE DATA			COMPENSATION FACTORS			CORRECT. FUNC.		SYNTHETIC RAND.	
			(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
No.	B.W. (Hz)	C.F. (Hz)	E/G -65°F (dB)	E/G +160°F (dB)	E/g AVG. (dB)	Tape Deck (dB)	Linear. Factor (dB)	Var. Factor (dB)	Correct E/g (dB)	Req'd. g/Hz (dB)	Req'd. E/Hz (dB)	Normalized (g ² /Hz)
43	25	963	31.7	32.7	32.3	0			32.3	9.3	41.6	4.34
44		988	31.9	32.5	32.2	0			32.2	9.3	41.5	4.24
45		1013	31.9	32.3	32.1	0			32.1	9.1	41.2	3.95
46		1038	31.8	32.1	32.0	0			32.0	8.9	40.9	3.69
47		1063	31.6	32.1	31.9	0			31.9	8.7	40.6	3.44
48		1088	31.4	32.0	31.7	0			31.7	8.4	40.1	3.07
49		1113	31.3	31.9	31.6	0			31.6	8.3	39.9	2.93
50		1138	31.2	31.8	31.5	+0.1			31.6	8.1	39.7	2.80
51		1163	31.0	31.6	31.3	+0.1			31.4	7.9	39.3	2.55
52		1188	31.0	31.5	31.3	+0.2			31.5	7.7	39.2	2.50
53		1213	31.0	31.4	31.2	+0.2			31.4	7.5	38.9	2.33
54		1238	30.7	31.3	31.0	+0.3			31.3	7.3	38.6	2.17
55		1263	30.7	31.3	31.0	+0.3			31.3	7.2	38.5	2.12
56		1288	30.6	31.1	30.9	+0.4			31.3	7.0	38.3	2.03
57		1313	30.4	30.8	30.6	+0.4			31.0	6.9	37.9	1.85
58		1338	30.3	30.9	30.6	+0.5			31.1	6.7	37.8	1.81
59		1363	30.3	30.5	30.4	+0.5			30.9	6.5	37.4	1.65
60		1388	30.2	30.3	30.3	+0.6			30.9	6.4	37.3	1.61
61		1413	29.7	29.6	29.7	+0.6			30.3	6.2	36.5	1.34
62		1438	29.0	29.0	29.0	+0.7			29.7	6.1	35.8	1.14
63	Y	1463	28.4	28.5	28.5	+0.7			29.2	5.9	35.1	0.971

WORKSHEET 3 of 4

R81-0629-058(3/4)W

WORKSHEET 3 of 4

R81-0629-058(3/4)W

Table 2-5 Tabulation Sheets for Synthetic Random Spectrum (Contd)

Tape No. <u>MULTIPLEX SYSTEM, Side:</u> Date: <u>1-29-81</u>												
Test Article: <u>MASS MOCKUP - REL DEMO TEST PROGRAM</u> S/N <u>-</u>												
Part No. <u>Analysis with HP 5472A</u> Axis <u>Z</u>												
SYSTEM FILTERS			SINE DATA			COMPENSATION FACTORS			CORRECT. FUNC.		SYNTHETIC RAND.	
No.	B.W. (Hz)	C.F. (Hz)	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
			E/G -65°F (dB)	E/G +160°F (dB)	E/g AVG. (dB)	Tape Feck (dB)	Linear Factor (dB)	Var. Factor (dB)	Correct E/g (dB)	Req'd. E/Hz (dB)	Req'd. E/Hz (dB)	Normalized (g^2/Hz)
64	25	1488	28.2	28.3	28.3	+0.8			29.1	5.8	34.9	0.927
65		1513	27.8	28.0	27.9	+0.9			28.8	5.6	34.4	0.826
66		1538	27.4	27.5	27.5	+0.9			28.4	5.5	33.9	0.736
67		1563	26.8	27.2	27.0	+0.9			27.9	5.3	33.2	0.627
68		1588	26.3	26.7	26.5	+0.9			27.4	5.2	32.6	0.546
69		1613	25.7	26.3	26.0	+1.0			27.0	5.1	32.1	0.487
70		1638	25.0	25.7	25.4	+1.0			26.4	5.0	31.4	0.414
71		1663	24.6	25.5	25.1	+1.0			26.1	4.8	30.9	0.369
72		1688	24.2	25.2	24.7	+1.0			25.7	4.7	30.4	0.329
73		1713	23.7	24.5	24.1	+1.1			25.2	4.6	29.8	0.287
74		1738	22.6	22.8	22.7	+1.1			23.8	4.4	28.2	0.198
75		1763	20.4	20.3	20.4	+1.2			21.6	4.3	25.9	0.117
76		1788	18.9	18.9	18.9	+1.2			20.1	4.2	24.3	0.0807
77		1813	17.8	18.0	17.9	+1.3			19.2	4.1	23.3	0.0641
78		1838	16.6	16.8	16.7	+1.4			18.1	4.0	22.1	0.0487
79		1863	15.1	15.3	15.2	+1.4			16.6	3.8	20.4	0.0329
80		1888	13.5	13.6	13.6	+1.5			15.1	3.7	18.8	0.0228
81		1913	11.1	11.2	11.2	+1.6			12.8	3.6	16.4	0.0131
82		1938	8.5	8.4	8.5	+1.6			10.1	3.5	13.6	0.0069
83		1963	6.0	6.0	6.0	+1.6			7.6	3.4	11.0	0.0038
84		1988	5.8	5.5	5.7	+1.7			7.4	3.3	10.7	0.0035

WORKSHEET 4 of 4

R81-0639-058(4/4)W

WORKSHEET 4 of 4

R81-0639-058(4/4)W

Table 2-6 HP5427A Vibration Control System Program

```

1. RELIABILITY DEMONSTRATION TEST - SYNTHETIC RANDOM VOLTAGE
   TEMPERATURE COMPENSATED

2. TRUE RANDOM MODE? YES;NO
   YES

3. AVERAGING WEIGHTING FACTOR?
   N = 8

   AVGS/LOOP?      DEGREES OF FREEDOM = 2K(2N-1) = 120
   K = 4

4. 3 SIGMA CLIPPING? YES;NO
   NO

5. MEASUREMENT MODE? YES;NO
   YES

   # OF AVGS?
   64

   AVGS/LOOP?      DEGREES OF FREEDOM = 2 x # OF AVGS = 128
   4

6. # CONTROL CHANNELS?
   1

7. CALIBRATION? MV/G

   CHANNEL A
   10.00

   CHANNEL B
   10.00

8. SYSTEM GAIN? G/VOLT @ INPUT
   30.00

9. SELF CHECK LEVEL? -DB
   -12.00

10. LEVEL SCHEDULE
    LEVEL(-DB), TIME(SEC), LEVEL(Grms), TIME(HRS)
    1. .00      300.      3.31      -
    2. -30.00   3600.     0.00      0.00 TO 1.00
    3. -5.00    108.      1.83      1.00 TO 1.03
    4. -9.00    3780.     1.17      1.03 TO 2.08
    5. -3.00    900.      2.34      2.08 TO 2.33
    6. .00      720.      3.31      2.33 TO 2.53
    7. -3.00    180.      2.34      2.53 TO 2.58
    8. -9.00    5112.     1.17      2.58 TO 4.00

11. LINE ABORTS ENABLED? -DB
    .00

    ABORT TIME? 10 SEC MAX
    5.00

12. MANUAL MODE ENABLED? YES;NO
    YES

13. LINE ALARM LIMIT? %
    100.00

14. RMS ABORT LIMIT? DB
    20.00

15. # LINES?
    512
R81-0639-067(1/2)W

```

Table 2-6 HP5427A Vibration Control System
Program (Contd)

```

16. LOWEST FREQ?
    15.00

17. HIGHEST FREQ?
    2000.00

    MAX FREQ. = 2500.00 HZ
    RESOLUTION = 4.88 HZ
    LOG HORIZ. = 3 DECADES

18. INPUT MODE?
    1=MAG.,FREQ,LIMIT+,LIMIT-(DB);
    2=SLOPE,FREQ,LIMIT+,LIMIT-(DB);
    3=DISC
    1

19. MAGNITUDE? GSQR/HZ, F= 15 HZ
    10.900000

20. MAG.,FREQ,LIMIT+,-?
    3.790000 26.00 3.00 3.00

21. MAG.,FREQ,LIMIT+,-?
    2.690000 37.00 3.00 3.00

22. MAG.,FREQ,LIMIT+,-?
    2.340000 50.00 2.00 2.00

23. MAG.,FREQ,LIMIT+,-?
    1.900000 84.00 3.00 3.00

24. MAG.,FREQ,LIMIT+,-?
    2.340000 141.00 3.00 3.00

25. MAG.,FREQ,LIMIT+,-?
    5.360000 163.00 3.00 3.00

26. MAG.,FREQ,LIMIT+,-?
    2.180000 188.00 3.00 3.00

27. MAG.,FREQ,LIMIT+,-?
    .561000 213.00 3.00 3.00

28. MAG.,FREQ,LIMIT+,-?
    .601000 238.00 3.00 3.00

29. MAG.,FREQ,LIMIT+,-?
    1.620000 288.00 3.00 3.00

30. MAG.,FREQ,LIMIT+,-?
    2.040000 313.00 3.00 3.00

31. MAG.,FREQ,LIMIT+,-?
    4.350000 488.00 3.00 3.00

32. MAG.,FREQ,LIMIT+,-?
    3.970000 588.00 3.00 3.00

33. MAG.,FREQ,LIMIT+,-?
    1.350000 638.00 3.00 3.00

34. MAG.,FREQ,LIMIT+,-?
    1.690000 663.00 3.00 3.00

35. MAG.,FREQ,LIMIT+,-?
    2.450000 686.00 3.00 3.00

R81-0639-067(2/2)W

```

Table 2-6 HP5427A Vibration Control System
Program (Contd)

```

36. MAG.,FREQ,LIMIT+,-?
    2.880000 713.00 3.00 3.00

37. MAG.,FREQ,LIMIT+,-?
    3.790000 813.00 3.00 3.00

38. MAG.,FREQ,LIMIT+,-?
    4.890000 838.00 3.00 3.00

39. MAG.,FREQ,LIMIT+,-?
    7.230000 863.00 3.00 3.00

40. MAG.,FREQ,LIMIT+,-?
    8.110001 913.00 3.00 3.00

41. MAG.,FREQ,LIMIT+,-?
    7.920000 963.00 3.00 3.00

42. MAG.,FREQ,LIMIT+,-?
    5.240000 1088.00 3.00 3.00

43. MAG.,FREQ,LIMIT+,-?
    2.620000 1388.00 3.00 3.00

44. MAG.,FREQ,LIMIT+,-?
    2.040000 1438.00 3.00 3.00

45. MAG.,FREQ,LIMIT+,-?
    1.440000 1488.00 3.00 3.00

46. MAG.,FREQ,LIMIT+,-?
    1.320000 1513.00 3.00 3.00

47. MAG.,FREQ,LIMIT+,-?
    1.560000 1538.00 3.00 3.00

48. MAG.,FREQ,LIMIT+,-?
    1.090000 1563.00 3.00 3.00

49. MAG.,FREQ,LIMIT+,-?
    .587000 1663.00 3.00 3.00

50. MAG.,FREQ,LIMIT+,-?
    .512000 1713.00 3.00 3.00

51. MAG.,FREQ,LIMIT+,-?
    .323000 1738.00 3.00 3.00

52. MAG.,FREQ,LIMIT+,-?
    .155000 1763.00 3.00 3.00

53. MAG.,FREQ,LIMIT+,-?
    .065900 1838.00 3.00 3.00

54. MAG.,FREQ,LIMIT+,-?
    .026200 1888.00 3.00 3.00

55. MAG.,FREQ,LIMIT+,-?
    .002200 1963.00 3.00 3.00

56. MAG.,FREQ,LIMIT+,-?
    .003800 1988.00 3.00 3.00

57. MAG.,FREQ,LIMIT+,-?
    .003800 2000.00 3.00 3.00

    RMS VALUE = 75.200 G'S

R81-0639-067(2/2)W

```

The H/P 5427A Vibration Control System was then operated in a closed-loop mode (the output fed directly into the control accelerometer channel) and the output voltage recorded on the left channel of the tape. Since the vibration program is exactly the same for the second four hours of the cycle, the procedure was repeated for the reverse direction of the tape. Figure 2-25 shows a spectrum analysis of the synthetic random voltage recorded on the tape.

The initial five minutes of the tape has random vibration at the 0 dB (3.31 G rms) level recorded on it. This is used by the operator to set the amplifier gain so that it reads 3.31 G rms on the true RMS meter. This is a one-time adjustment. (Zero on the tape counter occurs at the conclusion of this five-minute period. Therefore the period is not repeated on subsequent cycles because of the automatic tape reversal.)

PROGRAMMING OF SWITCHED EVENTS - The Reliability Demonstration program requires that five switched events, i.e., vibration, temperature, humidity, test article power, and test article cooling, be turned on and off at selected times in the program. Table 2-7 was prepared showing the timed sequence of these events. It should be noted that the vibration on and off command was timed to initiate operation several minutes in advance of the actual taped random signal that is on the left channel of the tape recorder. Humidity timing was also in advance of the requirement, since it takes about 10 minutes to fill and drain the humidity pan.

Programming of the right channel is accomplished using the Multiplex System programmer. With the tape in the record mode, the appropriate switch on the program is turned on for 2 to 3 sec. at the scheduled time of each event. The 11 kHz programming switch is left on during the entire time the tape is running.

To satisfy the eight-hour test cycle requirement, the tape is stopped at the conclusion of the first four hours of the program, and a $\frac{1}{4}$ " piece of aluminum tape is bonded to the recording tape. In the normal tape playback operation mode, the aluminum tape will automatically activate the tape reverse solenoid, causing the second four hours of the program to be played. In order to record the second half of the program, the tape reels must be interchanged (because the

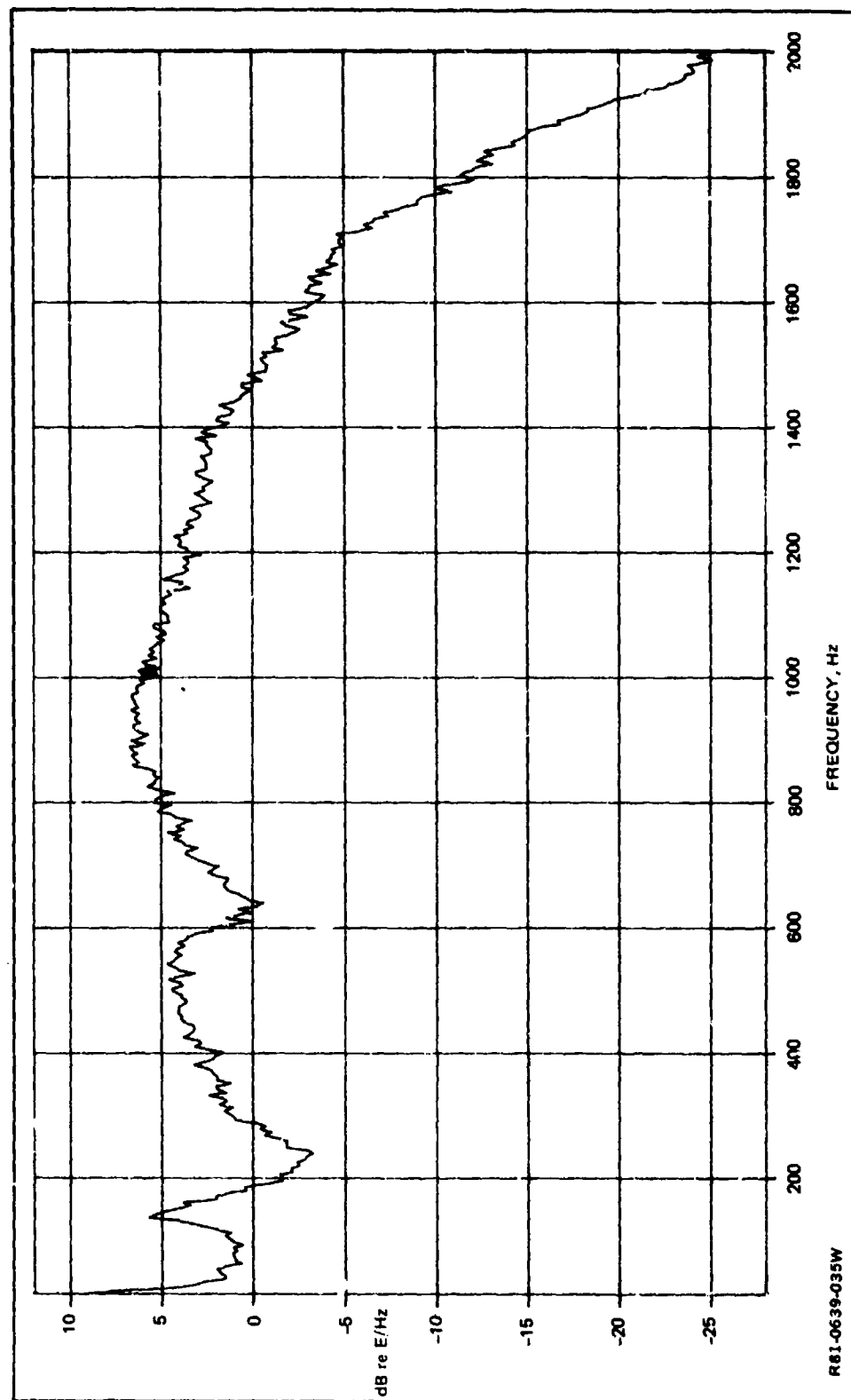


Fig. 2-25 Multiplex System: Recorded Random Voltage, Temperature Compensated

Table 2-7 Multiplex System - Reliability Demonstration Test Event Schedule

PROGRAM TIME HR	TAPE COUNTER	VIB	TEMP	HUM	PWR	COOL	VIB LEVEL	REMARKS
-0.08	9700	ON	OFF	OFF	OFF	OFF	0 DB	SETUP PHASE
-0.02	9920	OFF	"	"	"	"	0 DB	"
0.00	0000	"	ON	"	"	"	-	START
0.50	0470	"	"	"	ON	"	-	
0.75	0724	ON	"	"	"	"	-	
1.00	0960	"	"	"	"	"	-5 DB	
1.03	0991	"	"	"	"	"	-9 DB	
2.08	2129	"	"	"	"	"	-3 DB	
2.33	2426	"	"	"	"	"	0 DB	
2.53	2672	"	"	"	"	"	-3 DB	
2.58	2735	"	"	"	"	"	-9 DB	
3.83	4548	"	"	ON	"	"	-9 DB	
4.00	4849	OFF	"	"	OFF	"	-	
4.00 *	4852	"	"	"	"	"	-	* TAPE REVERSES
4.50	4013	"	"	"	ON	ON	-	
4.75	3641	ON	"	"	"	"	-	
5.00	3287	"	"	OFF	"	"	-5 DB	
5.03	3250	"	"	"	"	"	-9 DB	
6.17	1850	"	"	"	"	"	-3 DB	
6.41	1580	"	"	"	"	"	0 DB	
6.53	1450	"	"	"	"	"	-3 DB	
6.58	1400	"	"	"	"	"	-9 DB	
7.98	0004	OFF	OFF	"	OFF	OFF	-	
8.00 *	0000	"	"	"	"	"	-	* TAPE REVERSES

recorder does not have recording heads for the reverse direction) and the balance of the program recorded.

The recording, which has the random signal on the left channel and the switching events on the right channel, was accomplished simultaneously. This is essentially a real-time process with four hours required per side to make the recording. The tape recorder does permit separate recording of each channel, but starting and stopping of the right channel recording should be avoided since it will result in intermittent interruption of the tape running signal which controls the cam drive motor.

Timing synchronization between the tape program and the temperature cam is unregulated and relies on the tape cycle to equal exactly the cam rotation period. Since anticipated errors of 2 to 3 minutes per cycle can add up to significant mistiming after a week of operation, it is recommended that the cam be manually resynchronized with the tape every 24 to 48 hours.

2.3.4.2 Short Demonstration Test Program - As mentioned previously, a 30-minute test program was recorded to serve as a laboratory demonstration program to show the capabilities of the Multiplexer system. The test profiles were taken from the eight-hour reliability demonstration and re-sequenced to provide as many programmed events as practical within the 30-minute test period. Since the chamber thermal response is too slow to perform a complete hot-cold cycle within the test period, the end of the high humidity portion of the eight-hour reliability demonstration cam was used for this demonstration tape. The test profile is shown graphically in Figure 2-26.

RANDOM NOISE PROGRAM - The random noise signal was derived and recorded on the tape essentially the same as it was for the eight-hour Reliability Demonstration test. One change, however, was made to demonstrate the versatility of the tape method for applying dynamic stimulation. Data from a high rate gattling gun cannon firing was mixed with the random noise signal and recorded on the second side of the tape. A 100-round burst at a rate of 6000 rounds per minute was added to the 2.34 G rms random, and a 100-round burst at a rate of 4000 rounds per minute was added to the 1.17-g rms random level. This resulted in short-duration peak acceleration levels of about 11 g. Figure 2-27 and 2-28 show typical acceleration time histories of a 100-round cannon burst. This

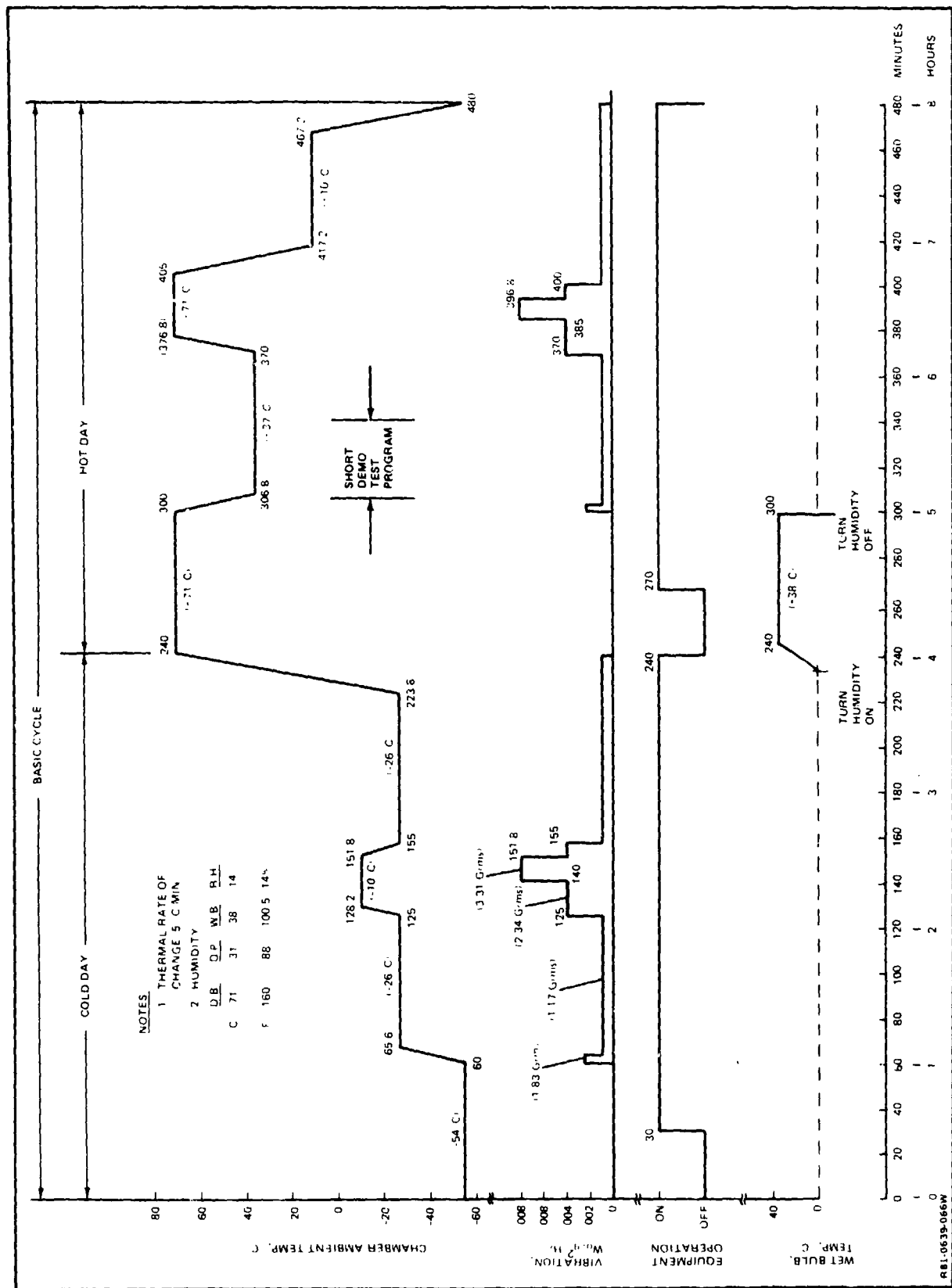


Fig. 2-26 Reliability Demonstration Test Profile - Short Demo

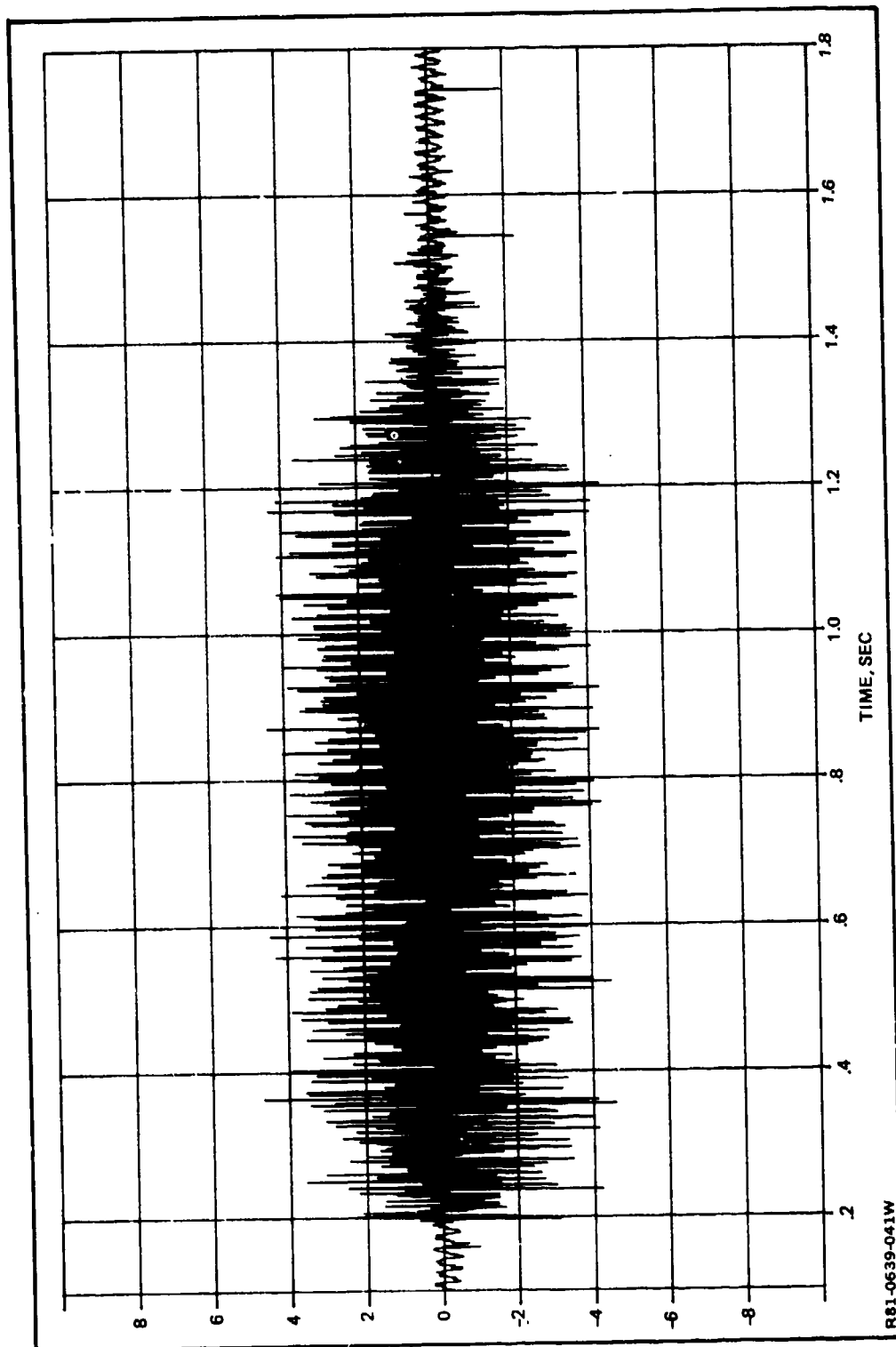


Fig. 2-27 Cannon Firing Time History, High Firing Rate, Vertical Axis Transient Capture

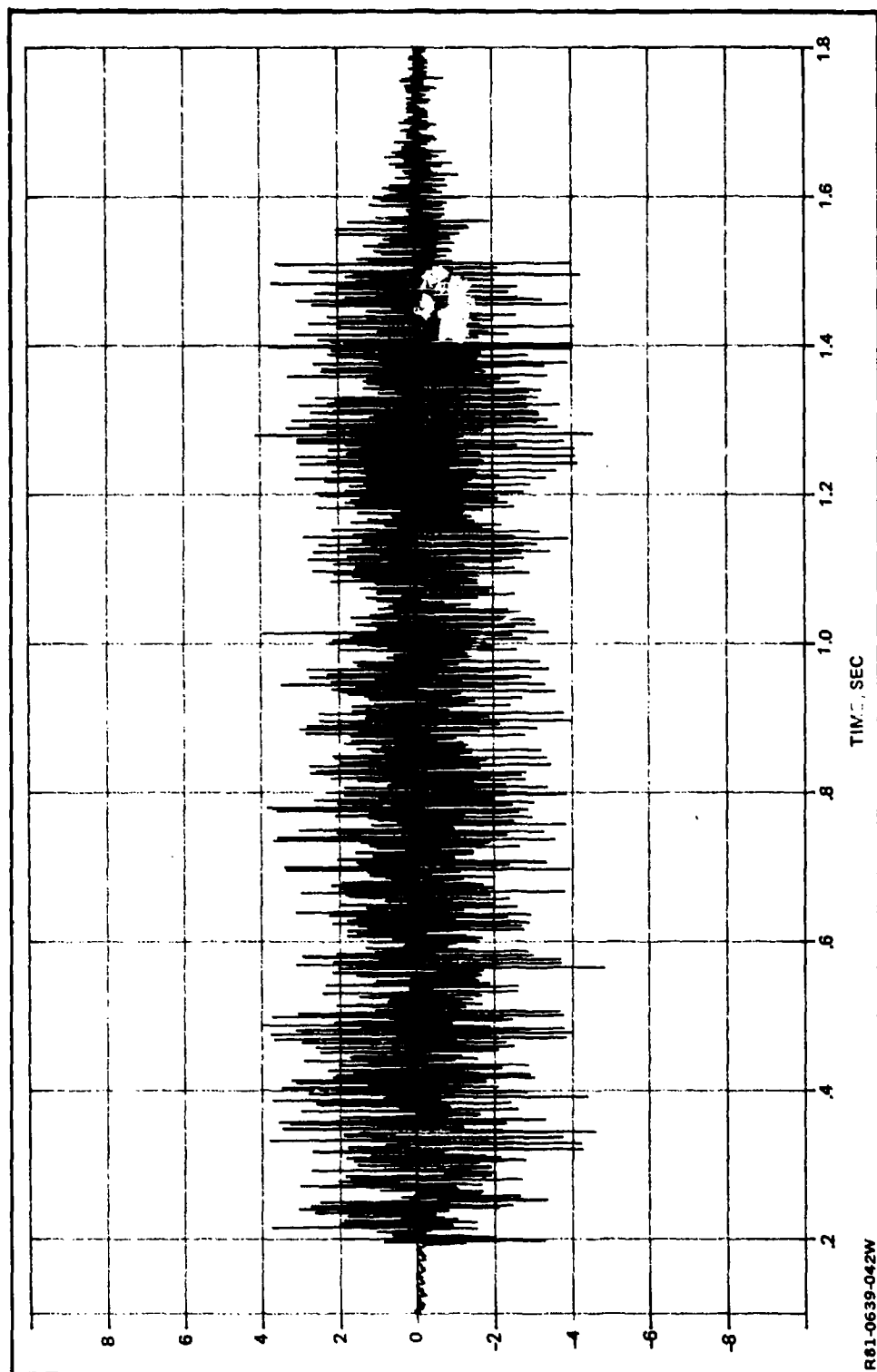


Fig. 2-28 Cannon Firing Time History, Low Firing Rate, Vertical Axis Transient Capture

simulation accurately reproduces the acceleration stress an avionic unit located near the cannon would experience during a gunfire mission.

Programming of Switched Events - The short demonstration test program required the switching of the same five events, ie., vibration, temperature, humidity, power on and off as the eight-hour Reliability program. The programming method was exactly the same, and Table 2-8 shows the time sequence of the test program as recorded on tape.

2.3.5 System Operation

Test operations consisted of running the Multiplex system through several test cycles while sampling test data and noting hardware and procedural problems. The initial test runs were made with the eight-hour Reliability Demonstration test program. During the final phases of the test program, test runs were made with the 30-minute short demonstration test program. Figure 2-29 shows a Multiplex test operation with the 8-hour program.

2.3.5.1 Reliability Demonstration Test Program - Almost all of the initial problems occurring during early test runs were with the environmental test chamber. Since the chamber's cam programmer controls the temperature and humidity, failures to follow the temperature profile are not the fault of the Multiplex system and so will not be discussed in detail. [It should be noted, however, that ability of the chamber to follow the required temperature - humidity profile should be verified in a normal mode prior to applying the Multiplex system.]

Timing of the turn-on of the humidity water is critical since it occurs in the transition range of -65°F to +160°F. It must be timed to occur after the freezing point is passed. For long-term tests, it would be advisable to install a temperature switch interlock to prevent water turn-on when temperature is below freezing.

Vibration control with the taped input was without problems. System overall linearity was excellent, resulting in nominal G rms readings at all four test levels. Spectrum analysis of the control accelerometer, taken at different test levels and test temperatures, were within the allowable tolerance band. (See Figure 2-30 for a typical plot.)

Table 2-8 Multiplex System — Short Duration Demonstration Test Event Schedule

PROGRAM TIME HR	TAPE COUNTER	VIB	TEMP	HUM	PWR	COOL	VIB LEVEL	REMARKS
-0.08	9778	ON	ON	ON	OFF	OFF	0 DB	SETUP PHASE
-0.02	9953	OFF	"	"	"	"	0 DB	"
0.00	0000	"	"	"	"	"	-	START
0.02	0047	"	"	"	ON	"	-	
0.07	0191	ON	"	"	"	"	-	
0.08	0238	"	"	"	"	ON	-5 DB	
0.13	0386	"	"	"	"	"	-3 DB	
0.18	0547	"	"	"	"	"	0 DB	
0.23	0713	OFF	"	"	"	"	0 DB	
0.25 *	0772	"	"	"	"	"	-	* TAPE REVERSES
0.27	0728	"	"	OFF	"	"	-	
0.28 x	0668	DN	"	"	"	"	-3 DB	x 100 ROUND CANNON
0.30	0615	"	"	"	"	OFF	-3 DB	FIRE - HI RATE
0.33	0505	"	"	"	"	"	-3 DB	
0.35 x	0450	"	"	"	OFF	"	-9 DB	x 100 ROUND CANNON
0.40	0294	"	"	"	"	"	0 DB	FIRE - LOW RATE
0.42	0245	"	"	"	ON	ON	0 DB	
0.45	0146	"	"	"	"	"	-5 DB	
0.47	0097	"	"	"	OFF	OFF	-	
0.48	0048	OFF	"	"	"	"	-	
0.50 *	0000	"	"	"	"	"	-	* TAPE REVERSES

R81-0639-056W



R81-0639-070W

Fig. 2-29 Multiplex Test Operation with 8-Hour Program

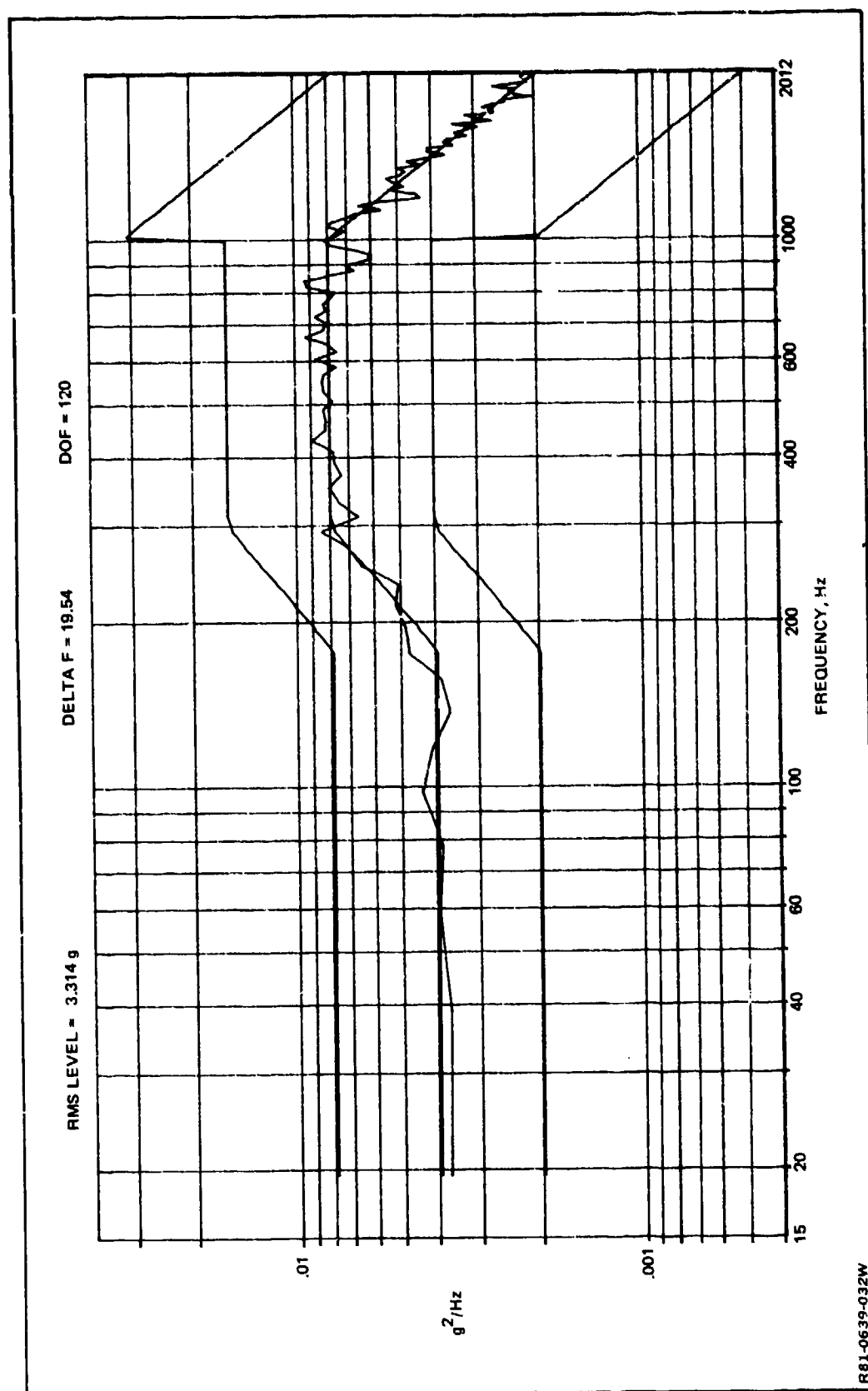


Fig. 2-30 Multiplex System Spectrum Analysis of Control Accelerometer, 2/6/81

The vibration dump circuit was initially wired through the tape running relay in addition to the g-rms meter relay. This was found to cause problems if there was any momentary interruption in the tape running signal (as might occur if any editing was done on the control channel of the tape). *The dump circuit was therefore wired only through the meter relay (see Para. 2.2.2).* No problems were encountered in the operation of the dump circuit as activated by the overttest meter relay.

The tape deck used in this program performed flawlessly. One feature of the deck, however, can cause a minor problem. The tape counter is electronic and, when power is turned off and then on again, the counter automatically returns to zero regardless of the position of the tape on the reel. Therefore, visible cueing tabs must be used on the tape to establish important counter references such as program start and end. It would be recommended that power be left on during the duration of the test program to avoid rewinding and re-zeroing the tape.

The system hold capability was checked and found satisfactory. The system goes into hold when the tape is stopped, with the exception of the vibration level which goes to zero when the tape is stopped. The test clock hold switch must also be activated to keep the test clock from advancing. The temperature - humidity condition at the start of the hold is held automatically by the chamber controller. Testing is resumed by starting the tape again and putting the test clock back in run position.

2.3.5.2 Short Demonstration Test Program - This 30-minute test program was recorded and run at the end of the Multiplex development program as a lab demonstration of the system capability. No problems with system operation were encountered. Spectrum analyses of the control accelerometers were all within tolerance. (See Fig 2-31 for a typical plot.)

The only unique feature of this test was the two simulated cannon bursts dubbed onto the random tape. Since the acceleration measures about 11 G rms for the short duration of the burst, the vibration dump switch had to be bypassed to prevent the dump circuit, which was set at 4 G rms, from activation during this portion of the program.

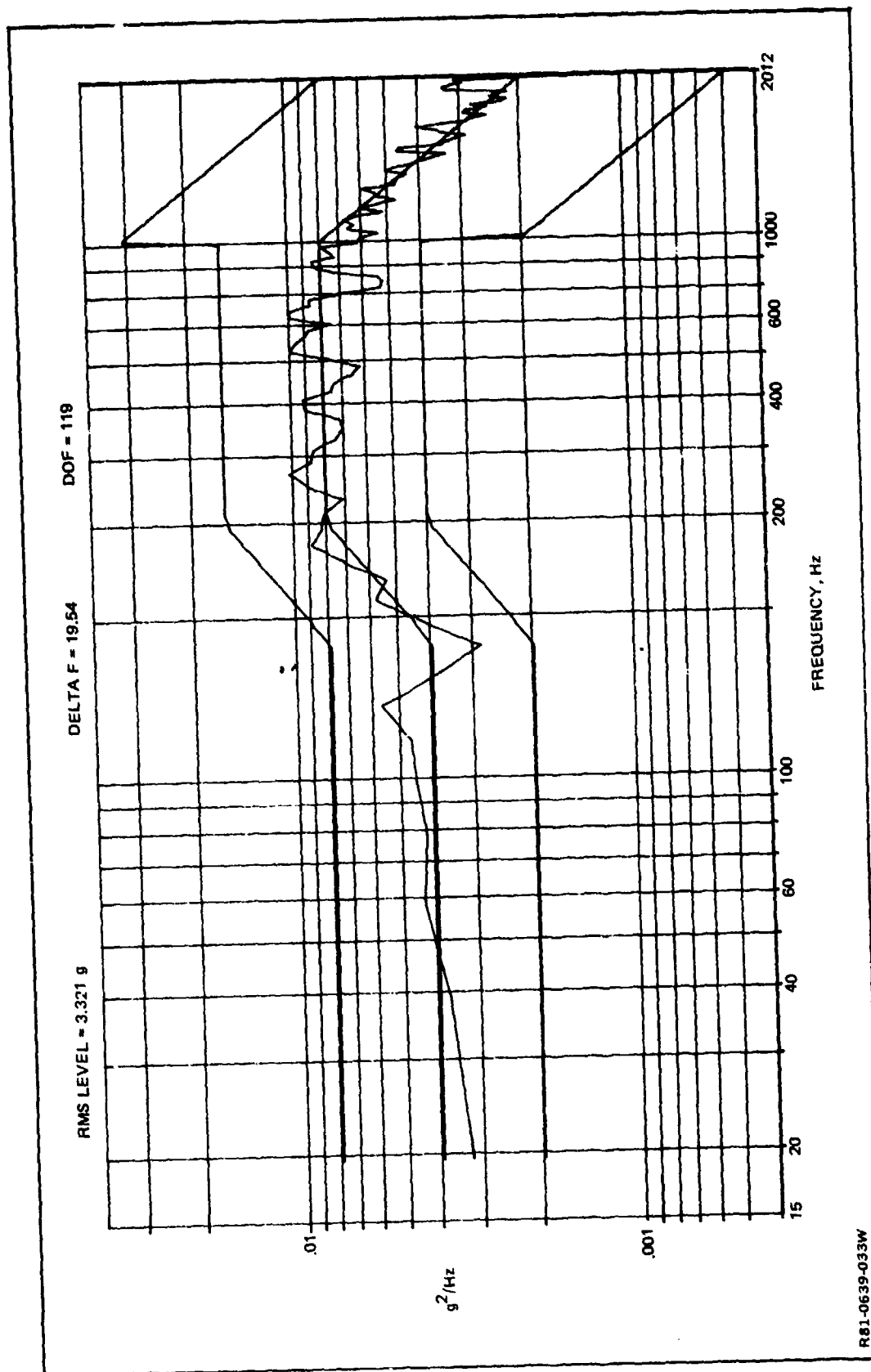


Fig. 2-31 Multiplex System Spectrum Analysis of Control Accelerometer, 3/19/81

2.3.6 Conclusions and Recommendations

2.3.6.1 Conclusions - The purpose of the Multiplex system was to provide a low-cost technique capable of providing open-loop control of environmental test equipment. The system was to provide control during the long-term Reliability Demonstration Test Programs, with a tentative cost to fabricate at less than ten thousand dollars. The system has demonstrated its ability to control the test environments with a hardware and labor cost well below the target costs.

The simplicity of design permits reproduction, checkout and utilization easily accomplished by personnel at the technician level. The prototype was designed for eight control channels. The addition or subtraction of channels is possible, permitting the unit to be tailored for a specific test. The low cost would also allow several small units to be fabricated and dedicated for each test program.

One potential problem with the system is the use of thin 1.0 mil tape in order to get a total of eight hours of testing. Problems with tape stretch or breaking may be encountered with prolonged (thousands of hours) usage.

2.3.6.2 Recommendations - Utilization of the present Multiplex System, and any similar system fabricated in the future, could be further enhanced by inclusion of the following recommendations:

- Test profiles, wherever possible, be shortened (to approx. 6 hr) to permit the use of heavier recorder tape, in order to minimize the potential problems of stretch & breakage
- Miniaturization of the display, switches, etc. would make the unit more portable and less bulky
- Redesign of the test clock to facilitate setting the accumulated test time each time the system is turned on
- Inclusion of an additional/ground circuit in the tape running circuit to permit bench checkout without actually running the test tape
- A more convenient method of interfacing test equipment than the present barrier strips.

2.4 MICROPROCESSOR SYSTEM

The objective of the microprocessor system was to provide an inexpensive programmed controller that would readily interface with all laboratory vibration and environmental equipment. It was intended to function with the random tape deck as a "stand-alone" test system, obviating the need for sophisticated control and measuring equipment in the laboratory.

The system described here meets all these requirements, and has the capability and versatility for expansion into other areas of testing as well.

2.4.1 Approach

The microprocessor features required to accomplish the objectives of the program can be summarized as follows:

- (1) Programmable in BASIC language to facilitate programming by inexperienced test personnel
- (2) Control interfaces to handle switching of a minimum of ten test functions
- (3) Data interfaces to handle a minimum of two temperature sensors and one accelerometer
- (4) Internal clock to schedule and keep track of test time
- (5) Sufficient memory and processor capability to provide constant monitoring and control of three variables in addition to scheduling events and storing data
- (6) Ease in loading and storage of test programs
- (7) Convenience peripherals - CRT display, terminal keyboard, and paper printer.

The initial search for this type of a computer system was in the home computer field in the hopes of keeping costs very low. While many of the home computers had the memory and capability to handle the type of program anticipated, they did not have the specialized interfaces necessary to handle thermocouple and accelerometer data inputs.

Further investigation led into the area of desktop computers. These systems have the required capability and instrumentation interfaces without the high price of the fullsize dedicated computer system. The details of the system finally purchased for the program are discussed in detail in Para. 2.4.3.

One further system requirement that was considered desirable was a method of verifying the spectral density of the applied random vibration, particularly in the case of a test article or system failure. This task was considered too complex to be programmed in BASIC so an alternative approach was implemented. It was decided to use one channel of the stereo tape deck to record the control accelerometer during the test. This would provide the capability to playback the data through a spectrum analyzer, if spectrum verification was required.

Two approaches were considered with regard to the taped random vibration test level profile. The profile could be programmed on the tape as was done for the multiplex system, or a single amplitude signal could be recorded on the tape and the microprocessor could change the level as required to meet the profile.

The first approach, using the multiplex-type system, has several disadvantages. Changing vibration level on the tape requires that the tape and computer program always be time synchronized, and the length of the program cycle is again limited by the duration of the tape program, or a maximum of eight hours.

The second approach was chosen since it would accommodate any length program cycle. It also could be made completely independent of time synchronization with the computer. This was accomplished by recording the synthetic random noise on an "endless loop" tape cassette. This type cassette is designed like an 8-track cartridge and is intended primarily for use in telephone answering cassette decks. It has a 12-minute cycle which continually repeats as long as the tape machine is running. Since the same random signal is continually sent to the computer, the tape deck becomes completely independent of the program timing. Details on the selection and characteristics of the deck are presented in Subsection 2.4.2.

One minor inconvenience in using the endless loop cassette is that it must be operated in the near-horizontal position to reduce winding friction. This required vertical mounting of our tape deck in the control console.

The control of the vibration level by the computer also presented two alternative approaches. The signal level could be automatically varied by the computer to bring the feedback accelerometer signal to the required test level, or the signal level could be varied using pre-calibrated resistors at the required programmed time without positive control from the feedback accelerometer.

The first method of automatic control was discarded for several reasons. It was inherently the least safe, since a loss of accelerometer signal would overdrive the shaker system. It would require a fast sampling rate to suppress cycling of the test level. Lastly, it would require the purchase of an additional type of D-A modular board.

For these reasons, the second approach was chosen and a circuit designed to provide the test level changes required using available relay switching logic.

2.4.2 Tape Deck Evaluation

The cassette recorder selected for use in the Microprocessor portion of the program was unique, as a review of the available manufacture's brochures and catalogs indicated. It was at that time, and may be presently, the only standard cassette recorder available that permits simultaneous recording during playback. The recorder is designed to allow recording on the right channel while playing back a previous recording on the left channel. In this program, this technique allowed recording response or control accelerometer data while the pre-recorded vibration spectrum, in accordance with NAVMAT P-9492, was being played into the shaker system. The selection of a standard cassette recorder, rather than the reel-to-reel recorder used in the multiplex system, allowed use of endless recording tapes presently available.

The recorder chosen was the TEAC-124M which was designed for audio-visual applications. The unit initially could not be used with a vibration system, primarily because of poor separation between adjacent heads, although minor problems were also present with the low-frequency response and output level. The supplier was requested to modify the basic recorder to meet the requirements of the program. The unit was returned to the supplier for these improvements and modifications, after which the recorder performance was checked.

The modification included the use of a four-track recording head, additional amplification, and improved low-frequency response.

The four-track head provided the needed head separation by using the two outside tracks in order to minimize the crosstalk between channels. The output level improvement was accomplished by insertion of another amplifier stage in the output. There are now two sets of output jacks on the rear of the unit. Low-frequency response was improved by adjusting the circuit capacitors to maximize the low-frequency response while diminishing the high-frequency (greater than 2 k Hz) response. The resulting recorder is unique to the program and can not be used as a normal recorder since only the 'A' side of the tape may be used and the upper frequency response is no longer adequate.

Upon arrival of the recorder in the laboratory, several tests were performed to verify its suitability. These tests included a frequency response checkout at 0 dB recording level for various bias and equalization modes. This test was needed to select the best recording and playback modes in an attempt to optimize the low-frequency response. Upon selection of the correct record and playback modes, a series of response plots was made. These plots were with recording levels from +3dB thru -40dB (six total), from which an average response curve (Fig. 2-32) was derived. Verification of the recorder output and low-frequency response was accomplished during these tests as well. The next check was the crosstalk level, which was accomplished by two methods.

First, a series of frequencies was recorded on the right channel while the left channel frequency response curves were played into a spectrum analyzer. The second test performed when the first check proved encouraging, was conducted with the vibration system. A sinusoidal sweep was recorded on the left channel and then played back through the shaker while the control accelerometer was recorded. The effects of the crosstalk, which initially could be heard through the shaker, were measured with a real-time analyzer.

Finally, when the recorder adjustment and response testing was completed with standard cassettes, the endless cassette was tested. The frequency

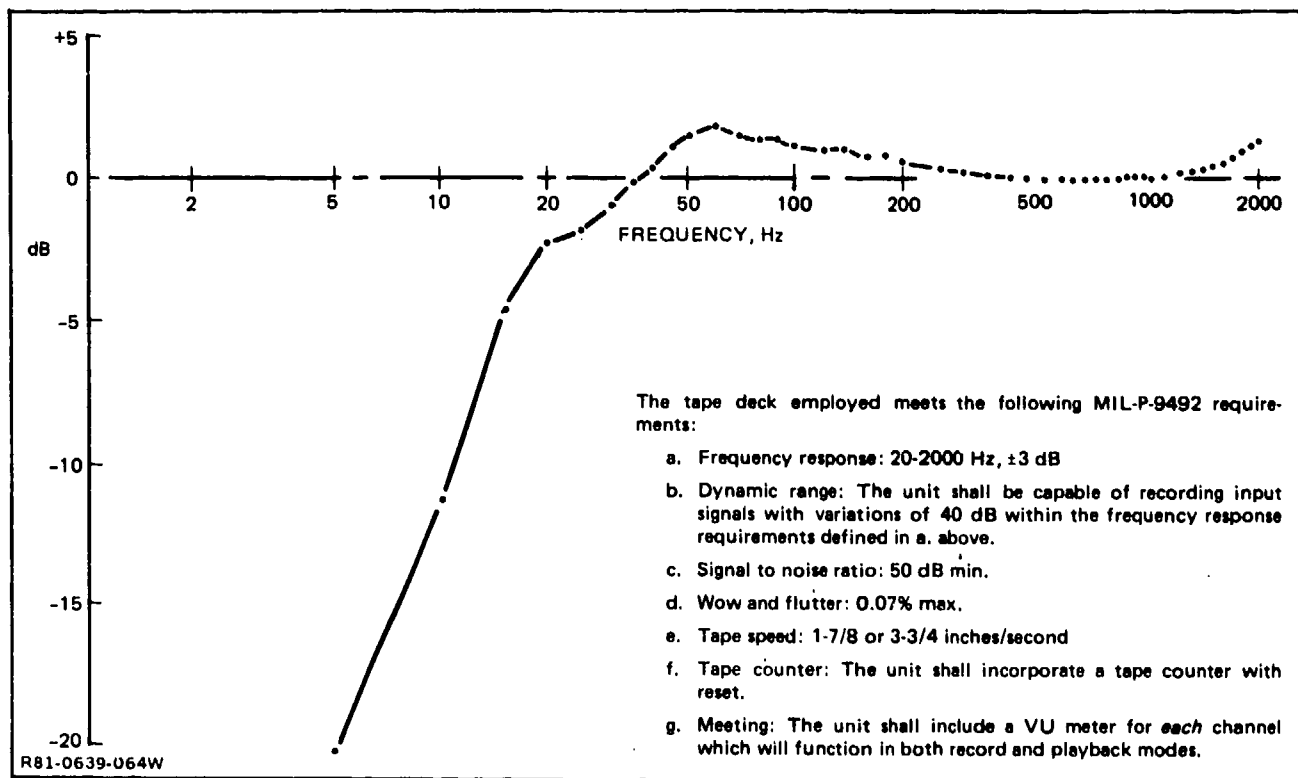


Fig. 2-32 Average Frequency Response Curve for TEAC - 124M Tape Deck

response of the tape and recorder was verified before its final inclusion in the Microprocessor system.

2.4.3 System Design

One of the main criteria in selection of the desktop microprocessor used in the program was that all interfaces and peripherals be readily available from the computer manufacturer so that the system design could proceed in a modular fashion. The design requirements were therefore organized as follows:

- Microprocessor
 - 48 K minimum RAM memory
 - BASIC language programmable
 - Typewriter input with CRT display
 - Tape or disk program storage
 - Internal clock for program timing
- Interfaces
 - Data input interface for following:
 - (1) Dry-bulb temperature (thermocouple)
 - (2) Wet-bulb temperature (thermocouple)
 - (3) Acceleration (high-level AC signal)
 - Switch outputs for the following:
 - (1) Temperature air circulator
 - (2) Humidity water
 - (3) Air heater
 - (4) Air cooler
 - (5) Water heater (humidifier)
 - (6) Water cooler (dehumidifier)
 - (7) Test article power
 - (8) Test article cooling
 - (9) Vibration
 - (10) Vibration overtest dump

- (11) Vibration Level control
- (12) Vibration Level control
- (13) Vibration Level control

- **Peripherals**

- Paper printer for record storage
- Stereo tape deck (discussed in previous section)

2.4.3.1 Microprocessor - The microprocessor chosen for this program was the Motorola Exorset 30. The computer uses the 8 - bit MC 6809 microprocessor. It is a desk top system complete with typewriter terminal, 9-inch CRT display, and two miniature floppy disk drives. It includes 48 k of dynamic RAM and operates in BASIC language. Table 2-9 gives the complete manufacturer's specification for the system. The list price at time of purchase was \$5995, which compared favorably with other systems examined. Fig. 2-33 shows the microprocessor and the printer.

2.4.3.2 Interfaces - The required interfaces outlined in Para. 2.4.3 fall into two general types:

- (1) A-D (Analog to Digital Conversion) Input
 - Two low-level (< 80 mv) DC thermocouple inputs
 - One high-level (> 500 mv) AC voltage signal from accelerometer charge amplifier
- (2) D-A (Digital to Analog Conversion) Output
 - Thirteen channels of switch closure, carrying from 300 mv AC at .2 amps (audio from tape deck) to 110 VAC at 5 amps (temperature air circulator)

A-D CONVERSION MODULE - The computer manufacturer had available a single-channel low-level A-D modular board with an expansion board to handle the two additional channels (capability of expansion to 16 channels).

The board had built-in linearization curves for the type thermocouples to be used in the temperature chamber. However, external cold junction compensation had to be used for each thermocouple channel.

Table 2-9 Manufacturer's Specification for Exorset 30

1. Main Controller Board Specifications

Power requirements (max)	5V/6A, +12V/1A, -12V/1A
Operating temperature	0 to 50 deg.C
Processor	MC6809
Word size	
Data	8 bits
Address	16 bits
Instructions	8, 16, 24, 32 bits
Instructions	59 instruction mnemonics
Addressing modes	10
Clock cycle time	1 microsecond
Baud rates	110 - 2400
Memory size	up to 32K bytes of RAM and up to 24K bytes of EROM available to user.
Serial interface	
Input	EIA RS-232C
Output	EIA RS-232C
Physical Characteristics	
Dimensions (WxD)	9.76 in. (248 mm) x 19.84 in. (504 mm)
Board thickness	.063 in. (1.6 mm)
I/O connectors	
Parallel interface	50-pin card edge connector
Serial interface	20-pin card edge connector
Cassette	5-pole DIN connector
CRT	Coax connector
Keyboard	ASCII: flex-tail, 23-pin or card edge, 50-pin Function keys: flex-tail, 8-pin or card edge, 20-pin

2. Floppy Disk Controller Board Specifications

Power requirements (max)	5V/0.8A, +12V/0.2A, -12V/0.15A
Operating temperature	0 to 50 deg.C
Memory size	16K bytes of RAM, 1K bytes of EROM (disk driver)
Interface	
Output	TTL open collector
Input	220/330 ohm line terminations
Physical characteristics	
Dimensions (WxD)	9.76 in. (248 mm) x 5.75 in. (146 mm)
Board thickness	.063 in. (1.6 mm)

R81-0639-059(1/4)W

Table 2-9 Manufacturer's Specification for Exorset 30 (Contd)

Connector, I/O	34-pin card edge connector
Connector, bus	86-pin card edge connector
3. Video Display Specifications	
Cathode Ray Tube	9 inches measured diagonally (22.8 cm) - 44 sq.inch viewing area (284 sq. cm) - 90 degree deflection angle - integral implosion protection - P4 (white) or P31 (green) phosphor.
Power input	12 Vdc at 900 milliamperes
Input signals	Composite video, 0.5 to 2.5 V composite P/P, negative sync, input impedance: 75 ohms
Video response	Within 3dB, 10 Hz to 12 MHz
Pulse rise time	20 V rise in 40 nanoseconds
Resolution	650 lines at center, 500 lines at corners
Distortion/linear	Less than 2%, measured with standard EIA ball chart and dot pattern
High voltage	9.0 kv at 50 microamps beam current
Horizontal blanking	11.0 microseconds maximum (includes retrace and delay)
Scanning freq.	Horiz. 15,750 +/- 500 Hz, Vert. 50 / 60 Hz
Controls	Brightness, vertical linearity, horizontal size, raster centering, vertical hold, horizontal hold
Dimensions	7.25 inches high (18.4 cm) 9.50 inches wide (24.1 cm) 9.48 inches deep (24.1 cm)
Weight	Net 8 lbs (3.6 kg)
Environment	Operating temperature 0 to 50 degrees C Storage temp. -40 to +65 C Operating altitude 10,000 ft max. (3048 m) Humidity 10% to 90% relative, non-condensing Designed to enable listing under UL spec. 478 Designed to comply with applicable DHEW rules on X-radiation
4. Mini-floppy Disk Drive Specifications	
Type	BASF 6106
Storage capacity	81,920 bytes/disk
Formatted	40 tracks/disk 2,048 bytes/track 16 sectors/track 128 bytes/sector
R81-0639-059(2/4)W	

Table 2-9 Manufacturer's Specification for Exorset 30 (Contd)

Access time	
Latency	200 ms max / 100 ms average
Track to track	12 ms
Average	240 ms
Settling time	50 ms max
Head load time	35 ms max
Rotational speed	300 RPM
Recording density	2768 BPI (inside track)
Flux density	5536 FCI
Track density	48 TPI
Track radius	2.25 in. (57.15 mm) (track 0) 1.4375 in. (36.5125 mm) (track 39)
Encoding method	FM
Media requirements	BASF 606 or equivalent
Environment	
Operating temp.	10 to 50 de C
Relative humidity	20 to 80 %
Power requirements	+5 Vdc / 0.5 A max, max 50 mVpp ripple +12 Vdc / 0.6 A max, max 100 mVpp ripple Drive motor start current 1.4 A max, 1.2 A typ. for 50 ms Head load start current 0.7 A for 50 ms
Power dissipation	10.5 W operating 4.0 W stand-by (motor off) 8.0 W motor on and desselect
Mechanical dimensions	
Width	5.75 in. (146.1 mm)
Height	2.11 in. (53.5 mm) drive, 3.25 in. (82.5 mm) front panel
Depth	7.48 in. (190.0 mm)
Weight	3.087 lbs. (1.4 kg)
5. Keyboard Specifications	
ASCII keys number	61
Output	8 x 8 + 6 x 1 matrix
Function keys number	16
Output	4 x 4 matrix
Contacts	screened mylar technology or mechanical
"On" resistance	< 200 ohms
Physical dimensions	16.42 in. x 6.30 in. max. (417 x 160 mm max) (outline dim.)
R81-0639-059(3/4)W	

Table 2-9 Manufacturer's Specification for Exorset 30 (Contd)

6. Power Supply Specifications	
Input voltage	95 to 125 / 205 to 250 VAC 47 to 420 Hz single phase
Output voltages	+5 Vdc / 10 A, 2mV RMS ripple -12 Vdc / 1.0 A, 1 mV RMS ripple +12 Vdc / 5.0 A, 1 mV RMS ripple
Calibration range	+5 Vdc +/- 0.5 Vdc +/- 12 Vdc +/- 1.0 Vdc
Over-voltage protection	5 Vdc output - output rise to 7 V reduced to 5 V or less within 50 microseconds
Power fail (Transients)	5 Vdc : +7 V / -0.5 V max +12 Vdc : +17 V / -0.3 V max
Remote sense	5 Vdc output - compensate up to 0.5 Vdc drop
Operating temp.	0 to 70 deg C ~ 70 % derating between 50 and 70 deg C
Dimensions	
Length	9.5 in. (241.3 mm)
Width	6.25 in. (158.8 mm)
Height	5.0 in. (127.0 mm)
7. Enclosure Specifications	
Material	Polyurethane, fire retardant
Dimensions	
Width	18.3 in. (465.0 mm)
Height	11.0 in. (280.0 mm)
Length	25.2 in. (640 mm)
Weight	13.89 lbs. (6.300 kg)
R81-0639-059(4/4)W	

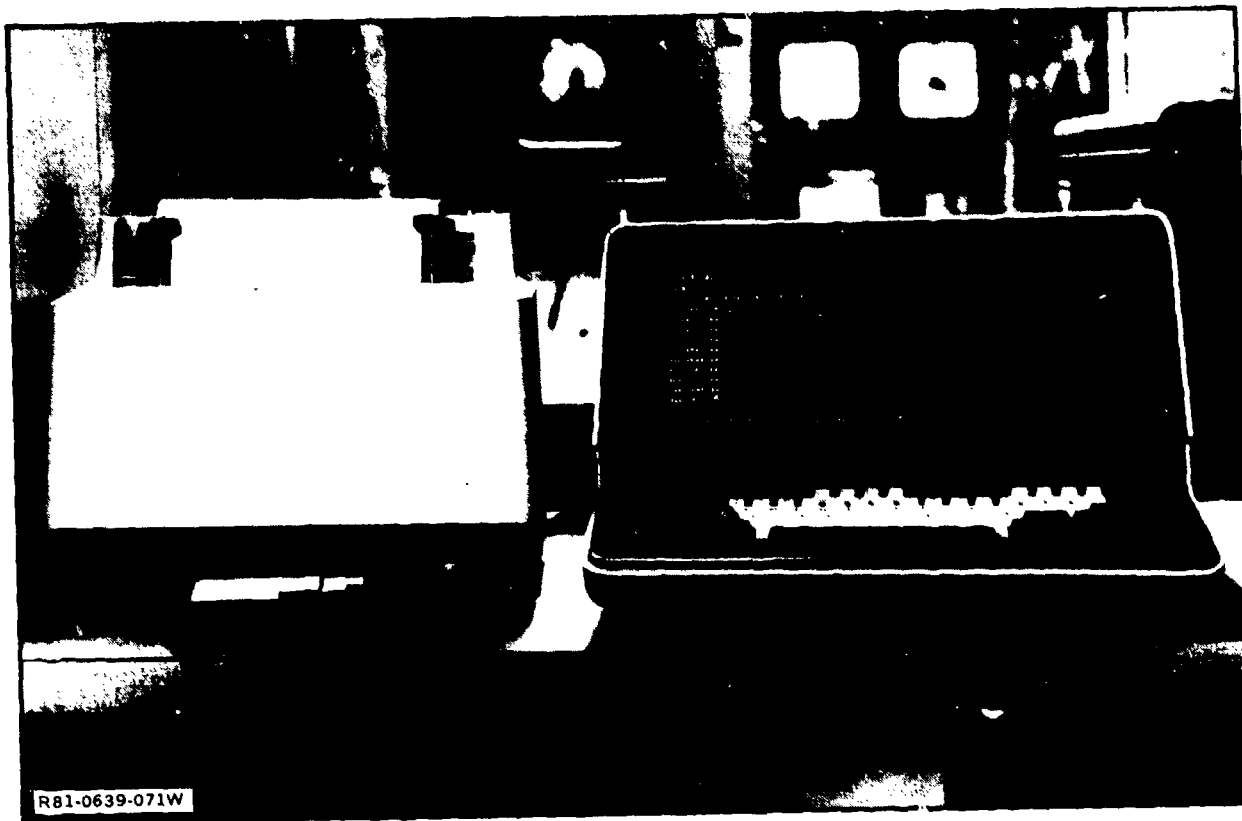


Fig. 2-33 Microprocessor and Printer

The high-level AC signal from the accelerometer had to be reduced to the 80 mv maximum handled by the board using an attenuator potentiometer. However, sampling the complex AC signal (random vibration) and integrating it to yield true RMS would require complex software and a very high sampling rate. Therefore, it was decided to process the signal external to the board using the DC output of the charge amplifier. This DC signal is proportional to the average of the AC signal, with some damping applied since it is used to drive the internal acceleration meter of the charge amplifier. This provides a relatively stable DC acceleration signal, requiring only a single sample for an accurate measurement. However, since the signal is proportional to average acceleration, it must be calibrated with a random noise source and a true-rms meter prior to use. This is accomplished with the pre-test calibration program described in Para. 2.4.5.1. The manufacturer's specification for this board is shown in Table 2-10.

D-A CONVERSION MODULE - The computer manufacturer had available a 16-channel digital output module board which provides 16 isolated switch closures using reed relays. The relays, however, are rated for a maximum of 0.5 amps at 28 Vrms: Since this is well below most of the switching requirements, the computer manufacturer supplied an additional relay board with 16 solid-state AC relays rated at 3.0 amps. These solid-state relays were activated with a 5-volt DC supply using the reed relay switch closures on the D-A board to supply the control logic.

These solid-state relays worked well for the high-voltage switching requirements of the environmental chamber. One circuit, the chamber air circulator, has a start-up current of about 5 Amp and had to have an intermediate stage using a 10-Amp relay.

However, these solid-state relays would not switch the low-level (500-800 mVrms) audio signals from the tape deck. These solid-state relays require a minimum load voltage of 24 VAC to switch. Therefore, another set of intermediate relays had to be used to switch the audio signals.

For future use, it is recommended that a solid-state relay board not be used. Rather, individual relays, sized for their required load, should be used with the D-A modular board. The manufacturer's specifications for these components are shown in Table 2-11.

Table 2-10 Manufacturer's Specification for A-D Module

CHARACTERISTICS	SPECIFICATIONS
Power Requirements	
MM15B	+5 Vdc $\pm 5\%$ at 1.2 A (max.)
MM15BEX	+5 Vdc $\pm 5\%$ at 200 mA (max.) plus 100 mA per channel
Micromodule Bus (MM15B)	
Address Bus	TTL compatible buffered input
Control Bus	TTL compatible buffered input
Data Bus	
Module Input	TTL compatible buffered input
Module Output	TTL compatible buffered output
Expander Control (P3)	TTL compatible input/output
Analog Input (P2)	
Operating (Full Scale)	± 25 mV, ± 55 mV, ± 80 mV
Common Mode Voltage	± 500 Vdc or 1000 V p-p ac
Maximum, continuous without damage	220 Vac
Impedance	>1000 megohms
Current	2 na (max.) at 70°C
Common Mode Rejection	150 dB at dc, 100 dB at 60 Hz
Normal Mode Rejection	>60 dB at 60 Hz
A/D Conversion	
Resolution	15 bits plus sign
Relative Accuracy (Linearity)	$\pm 0.01\%$ FSR ± 1 count
Quantization Error	$\pm 1/2$ LSB
3 Sigma Noise	<2 μ V RMS referred to input
Stability	
Tempco of Linearity	6 PPM FSR/°C
Tempco of Gain	20 PPM FSR/°C
Tempco of Offset	0.5 mV/°C max.
Conversion Time	
Random Channel Scan	133.33 ms max. for \pm Full Scale input 66.67 ms min. for zero volt input
Sequential Channel Scan of four or more channels	83.33 ms max. for \pm Full Scale input 16.67 ms min. for zero volt input
Operating Temperature	0° to 70°C
Physical Characteristics	
Width x Height	9.75 in. x 5.75 in.
Board Thickness	0.062 in.
Bus Mating Connector Types	
86-pin connector (1)	Stanford Applied Engineering SAC-43D/1-2 or equivalent
20-pin connector (1)	3M 3461-0001 or equivalent
Analog connector	Buchanan PCB3 or equivalent
R81-0629-060W	

Table 2-11 Manufacturer's Specifications

a) D-A MODULE		b) SOLID-STATE RELAYS			
NUMBER OF CHANNELS MP701		Characteristic	Min	Max	Unit
DIGITAL OUTPUT					
Watts (DC resistive load) max	16				
Amps (resistive load) max					
Voltage (resistive load) max					
Life (resistive load) min					
Initial contact resistance max					
Actuate Time					
Dc-Actuate time					
Bounce time					
TRANSIENT PROTECTION					
Continuous power rating					
Discharge capacity					
COMPUTER BUS					
All signals compatible with Motorola EXORciser and Micromodules system					
Logic Loading					
Output Coding					
POWER REQUIREMENTS					
Voltage					
Supply Drain max. MP701					
Supply Drain max. MP702					
ISOLATION VOLTAGE					
Between microcomputer bus and outputs					
Between outputs					
OPERATING TEMPERATURE					
STORAGE TEMPERATURE					

R81-0639-061W

RANDOM VIBRATION LEVEL SWITCHING - The test profile requires four different levels of random vibration at various times in the program cycle. As was discussed in Para. 2.3.1, it was decided to accomplish this by switching resistors into the audio path from the tape deck. *As a safeguard, the system was designed so that a 50k-Ohm resistor is always in series with the audio signal when vibration is switched on.* This, in effect, always switches the system to the lowest test level - 9db (1.17 G rms) when vibration is enabled. (Relay #9). To reach the higher test levels, an additional relay must be activated which applies another resistor in parallel with the 50 k resistor. For example to test at 0 dB (3.31 G rms), Relay #9 and #13 must be activated, which switches a 6 k resistor in parallel with the 50 k series resistor for an effective circuit resistance of 5.5 k Ω .

The resistance values required for a particular set of test levels can be readily determined empirically using variable resistors or a decade resistance box during the setup phase of the test.

PERIPHERALS - In order to have a permanent record of test temperatures, accelerations and tolerance compliance with respect to time, a printer was required for the system. The unit chosen was an IDS-440 manufactured by Integral Data Systems. It features automatic line buffering of 256 bytes to permit quick transfer of data from the computer without slowing system performance. The manufacturer's data sheets are shown in Table 2-12.

The requirement for two A-D boards and one D-A board exceeded the available spare bus connectors in the terminal (two available). Therefore, a four-board card cage had to be purchased for the computer. The manufacturer, however, did not have standard cable connectors to tie the computer bus to the card cage bus. This 86 wire cable had to be hand wired, using two cut-down extender boards to complete the card cage hookup.

The final system component required was the Stereo Tape Deck, which is described in detail in Para. 2.4.2.

2.4.3.3 Microprocessor Interfacing - The microprocessor interfaces with four segments of the test system:

- Temperature - humidity chamber
- Vibration shaker system

Table 2-12 Manufacturer's Specification for Printer

PERFORMANCE SPECIFICATIONS

- a. Serial Baud Rate: Switch selectable data rates of 110, 300, 600, or 1200 bits per second (bps).
- b. Character Density: 8.3, 10, 12, or 16.5 characters per inch (cpi), DIP switch selectable, plus enhanced (double width) characters at each density.
- c. Print Speeds: Maximum of 198 characters per second (cps) instantaneous at print density of 16.5 characters per inch (cpi); 144 cps at 12 cpi; 120 cps at 10 cpi; and 100 cps at 8.3 cpi.
- d. Maximum Sustained Throughput: 92 cps at print density of 16.5 cpi; 67 cps at 12 cpi; 56 cps at 10 cpi; and 45 cps at 8.3 cpi.
- e. Lines Per Minute: 275 lines per minute with 10 character lines; 42 lines per minute with full lines of 132 characters (at 16.5 characters per inch).
- f. Maximum Line Length: 66, 80, 96, or 132 characters across an 8-inch print width, at 8.3, 10, 12, or 16.5 cpi respectively.
- g. Buffering Capabilities: Automatic multiple line buffering. Standard size of 256 bytes and optional size of 2048 bytes for full CRT screen and graphics buffering (supplied with graphics plotting option).
- h. Lines Spacing: Six or eight lines per inch, DIP switch selectable.
- i. Forms Control: Eight DIP switch selectable form sizes of 3, 3.5, 4, 5.5, 7, 8.5, 11, and 14 inches with DIP switch enabled 1 inch perforation skip. Top of form controlled manually (via operator control) when off line, or automatically during on line operations via ASCII FF control code.

PERFORMANCE FEATURES

Microprocessor Controller	Microprocessor based hardware/firmware architecture directly supervises and controls all print operations, and enables operator issued ASCII control codes to select/change configuration and control functions.
Built-In Diagnostics	Automatic test of microprocessor program and buffer memory during power-up. An additional operator initiated test prints repetitive patterns for visual checks of print quality.
Serial/Parallel Interfaces	Serial RS-232-C, or Parallel TTL level interface (compatible with Centronics).
Character Set	Full upper and lower case ASCII, with 12 standard and one optional control codes.
Paper Drive	Stepper motor driven pinfeed tractor.
Paper Types	Pinfeed fanfold, or roll in widths from 1.75 to 9.5 inches, including pinfeed holes.
Print Format	Four selectable character densities from 8.3 to 16.5 characters per inch, plus enhanced mode (double width) characters at each density.
Print Speed	Up to 198 cps (instantaneous) at 16.5 cpi, with sustained throughput to 92 cps.
Line Length	Variable, up to 132 characters at 16.5 cpi (maximum eight inch print width.)
Page Format	Eight selectable form lengths from 3 to 14 inches, with selectable page boundary skip of 1 inch. Selectable line spacing of 6 or 8 lines per inch.
Buffering	Automatic multiple line buffering of 256 bytes (standard) or 2048 bytes (supplied with optional graphics plotting mode).
Ease of Operation	Operator accessible controls and indicators enable fast, simple, operations.
Maintainability	Built-in automatic and operator initiated diagnostics aid troubleshooting. Modular construction allows rapid repair or replacement of parts.

R81-0639-062W

- Tape deck
- Test article support equipment

Figure 2-34 shows a block diagram of these interfaces.

For convenience, the tape deck and the A-D and D-A modules were mounted in the Multiplex system console. This permitted both systems to be connected to the exciter, chamber and test article support equipment interfaces, which were wired to the multiplex console. Figure 2-35 shows the back of the multiplex console, showing these interfaces and the microprocessor components.

The mounting of the tape deck is shown in Figure 2-36. This swing-out mounting was closed during test runs. This provided the horizontal plane that the "endless loop" cartridge required.

As noted previously, the test article support equipment was limited to a cooling blower and simulated test article power.

2.4.4 System Programming

Four programs were written to conduct various phases of the test procedure. The names of the programs and the function each performs are listed in Table 2-13. Several memory locations are reserved for the timing, transducer input, and instrumentation switching capabilities. These memory locations are listed in Table 2-14. A description of each program along with flow charts Figure 2-37 to 2-43, and listings, Table 2-15 to 2-18 follows.

2.4.4.1 "CALIBRATE" - The CALIBRATE program is run by inputting the channel desired for readout 0, 1, or 8. Lines 80 to 130 will print out the dry bulb temperature continuously if channel 0 is selected. Lines 160 to 220 perform a similar function for channel 1, the wet bulb temperature. Printout of DC voltage proportional to rms acceleration is performed by lines 250 to 300 for channel 8.

Depressing key F1 allows the user to repeat the program and select a different channel. Depressing key F4 stops execution of the program.

2.4.4.2 "SETUP" - To run this program, the number of switches and the switch numbers are typed in on the console keyboard. Lines 80 to 130 perform the function of obtaining the switches to be turned on. Lines 140 to 270 perform a calculation to obtain an integer that must be written into memory locations ECFE

and ECFF to activate the desired switches. The table below describes the bit pattern for these two memory locations and the switches that are activated by each bit.

ECFF	ECFE	MEMORY LOCATION
7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0	BIT
16 15 14 13 12 11 10 9	8 7 6 5 4 3 2 1	SWITCH CONTROLLED
R81-0639-050W		

By writing a one into a bit location, the switch is activated. Writing a zero turns off the switch.

Depressing key F1 allows the user to rerun the program and depressing key F4 terminates the program.

2.4.4.3 "DEMO" - "DEMO" was written to monitor and control the system to the profile presented in Figure 2-44. A typical printout obtained from running the program is presented in Table 2-19. The program consists of several sections as shown in Figure 2-45. Initially, the stabilization portion of the program is run, lines 120 to 230. Here, the start time is input and the program determines the required temperature for the time point. Chamber switches are then activated to bring the chamber temperature to within acceptable tolerances of the required value. Once the temperature is acceptable, the stabilization portion of the program is complete.

The next phase of the program monitors and controls the various test profiles. Lines 250 and 450 are dedicated to start and control of the time interval. The microprocessor clock is programmed to run on a one-half second time interval. Every 15 seconds, 30 one-half second counts, monitoring and control functions are performed. A subroutine located at lines 760 to 1000 accepts the temperature and vibration inputs and calculates the required values. The measured and required values are compared and, if out of tolerance conditions exist, warnings are output. This procedure is performed in lines 470 to 680. This portion of the program also checks for excessive out of tolerance conditions and shuts the system down if these conditions are detected, lines 710 to 750. Excessive out of tolerance conditions exist if the temperature is at or in excess of 93°C, or -73°C or less, or if the acceleration is 4-g rms or greater.

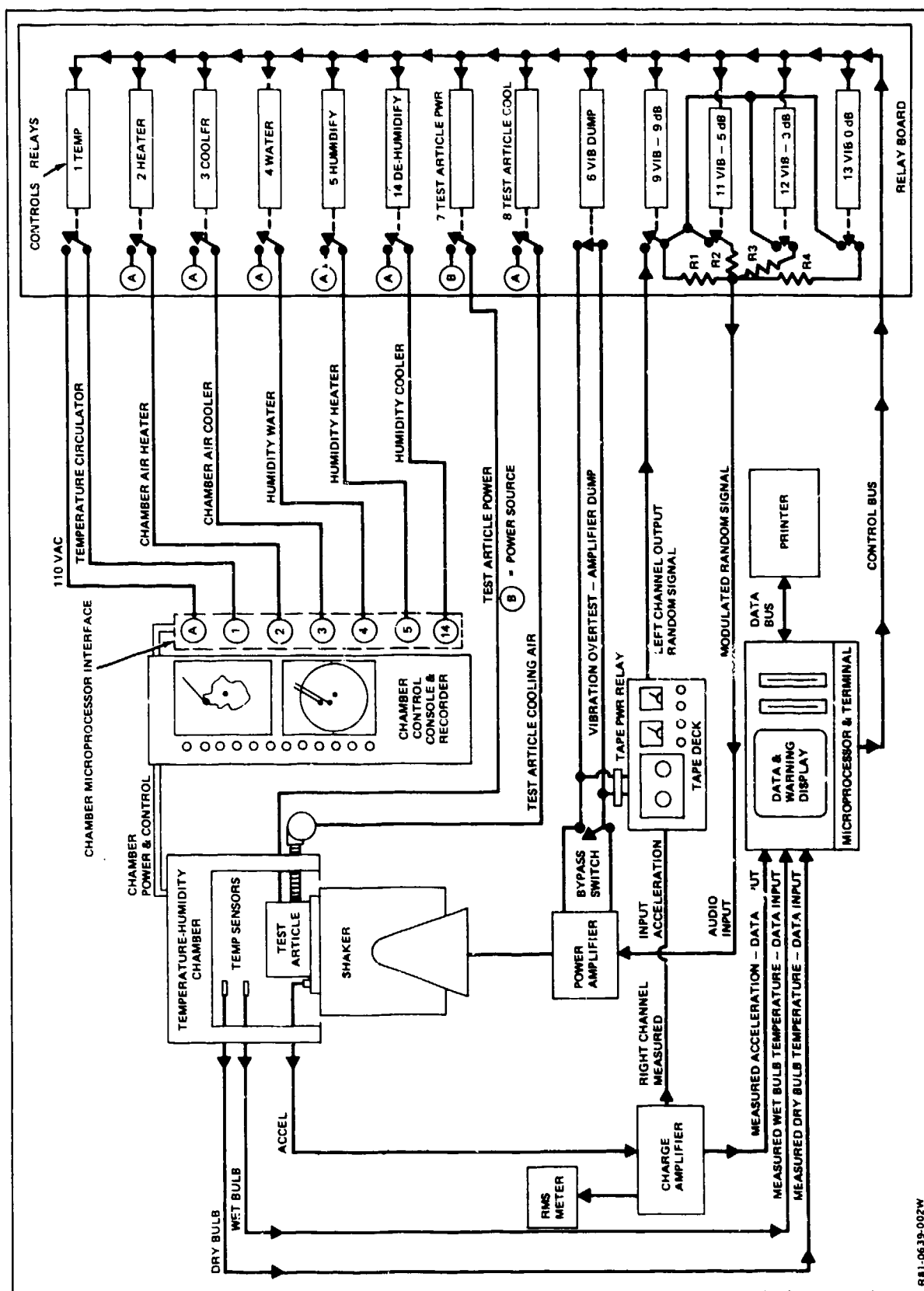


Fig. 2-34 Microprocessor Test System

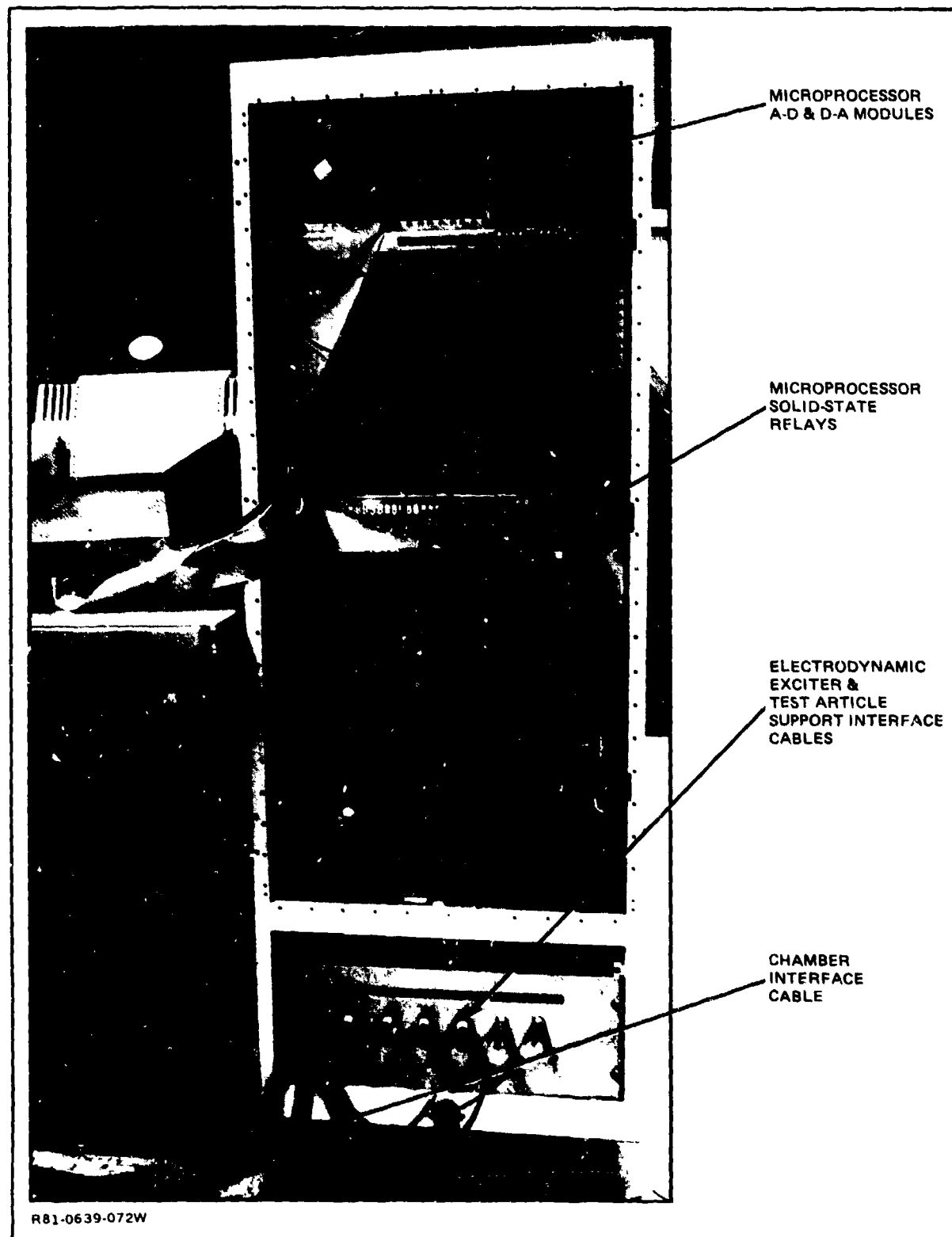


Fig. 2-35 Microprocessor Components in Multiplex Console

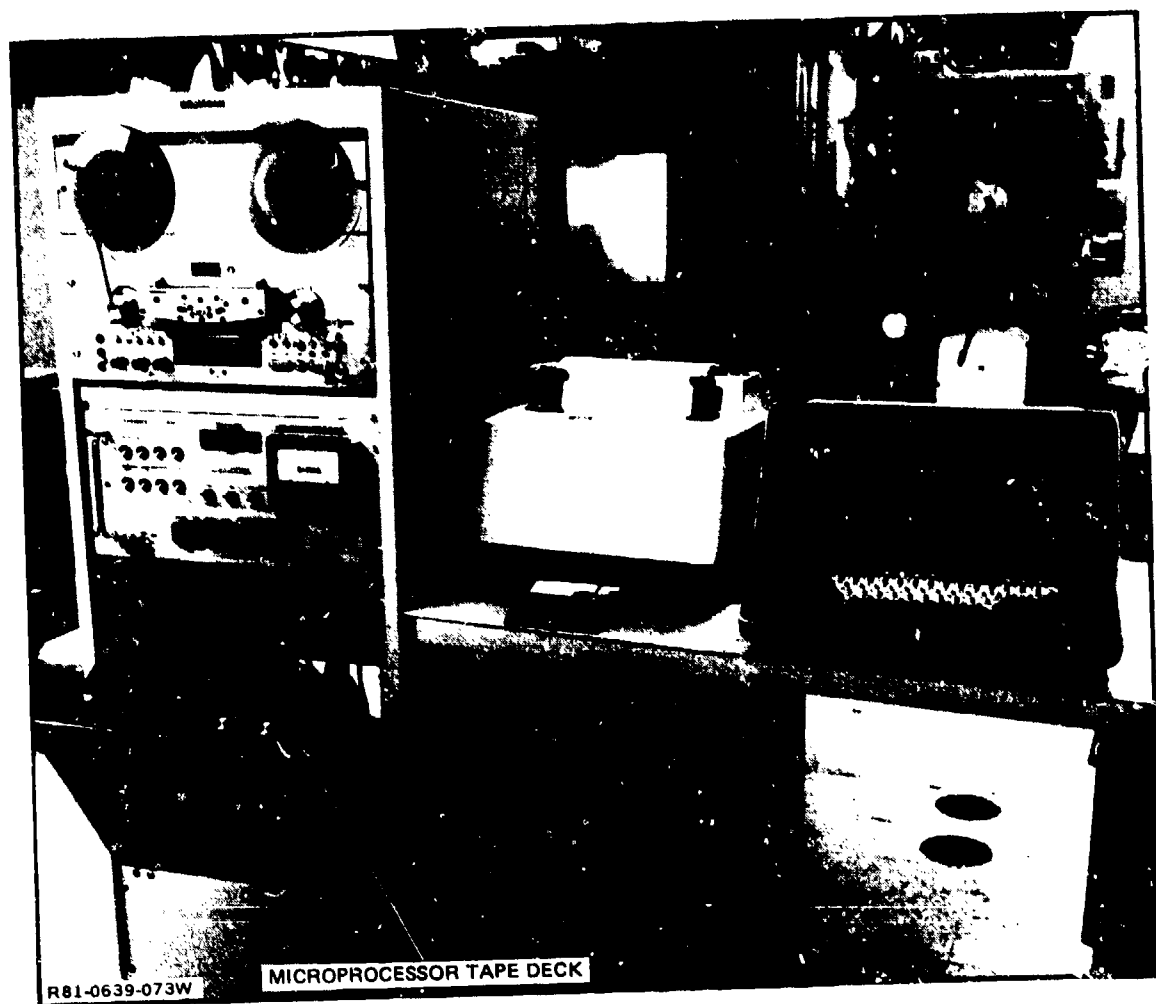


Fig. 2-36 Microprocessor Tape Deck in Multiplex Console

Table 2-13 Program Names and Functions

NAME	FUNCTION
CALIBRATE	USED TO CALIBRATE OR ADJUST TEMPERATURE AND VIBRATION READOUTS.
SETUP	ACTIVATES THERMAL CHAMBER, VIBRATION SHAKER AND TEST ARTICLE SWITCHES.
DEMO	CONTROLS AND MONITORS THE SYSTEM TO FOLLOW DEMONSTRATION PROFILE.
TROUBLESHOOT	USED TO SOLVE PROBLEMS THAT ARISE DURING CONTROL AND MONITORING OF THE TEST PROFILES.
RELDEN	CONTROLS AND MONITORS THE SYSTEM TO FOLLOW EIGHT HOUR PROFILE.

Table 2-14 Reserved Memory Locations*

TIMER	EF20, EF21, EF26
THERMOCOUPLE AND VIBRATION INPUTS	ED11, ED12, ED13
SWITCHES	ECFE, ECFF
*VALUES ARE LISTED USING HEXADECIMAL NOTATION	
R81-0639-048W	

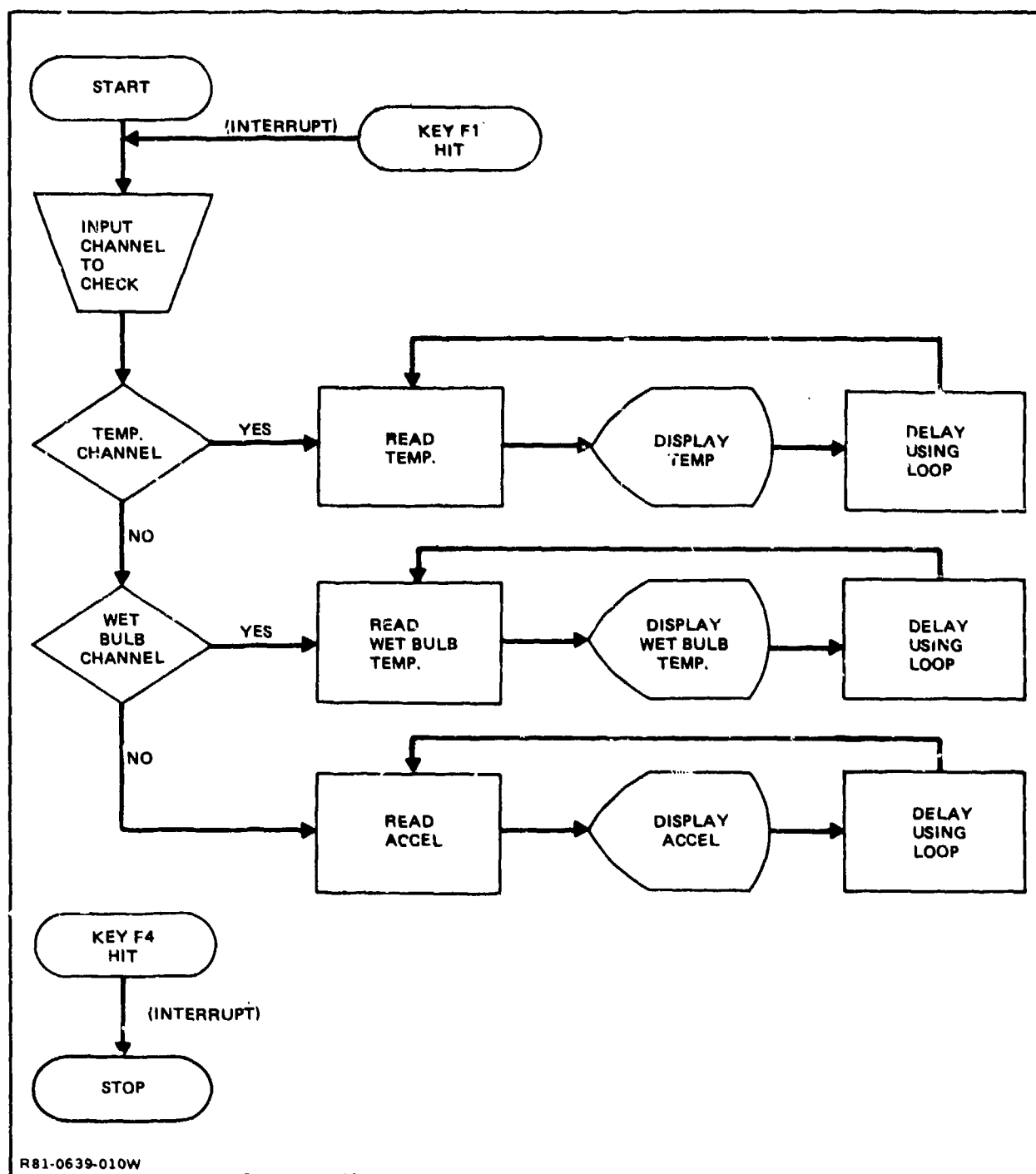


Fig. 2-37 CALIBRATE Flowchart

Table 2-15 Program CALIBRATE

```

00010 ON KEY 1 THEN GOSUB 360
00020 ON KEY 4 THEN GOSUB 390
00030 BYTE A1 ADDR $ED11
00040 INTEGER B1 ADDR $ED12
00050 PRINT "INPUT CHANNEL TO BE CALIBRATED 0,1, OR 8"
00060 INPUT CHANNEL
00070 IF CHANNEL>8 THEN 160
00080 A1=$0
00090 IF A1=$0 THEN 110
00100 GO TO 90
00110 TEMP=B1/64
00120 PRINT CHR$(27); CHR$(69)
00130 PRINT "THE DRY BULB TEMPERATURE IS ";TEMP
00140 GOSUB 330
00150 GO TO 80
00160 IF CHANNEL>1 THEN 250
00170 A1=$1
00180 IF A1=$1 THEN 200
00190 GO TO 180
00200 TEMP=B1/64
00210 PRINT CHR$(27); CHR$(69)
00220 PRINT "THE WET BULB TEMPERATURE IS ";TEMP
00230 GOSUB 330
00240 GO TO 170
00250 A1=$8
00260 IF A1=$8 THEN 280
00270 GO TO 260
00280 VOLT=(B1/32767)*80
00290 PRINT CHR$(27); CHR$(69)
00300 PRINT "THE ACCELERATION LEVEL IS ";VOLT
00310 GOSUB 330
00320 GO TO 250
00330 FOR I=1 TO 70
00340 NEXT I
00350 RETURN
00360 PRINT "WE HAVE A HOLD"
00370 GO TO 50
00380 RETURN
00390 STOP
00400 RETURN

```

R81-0639-052W

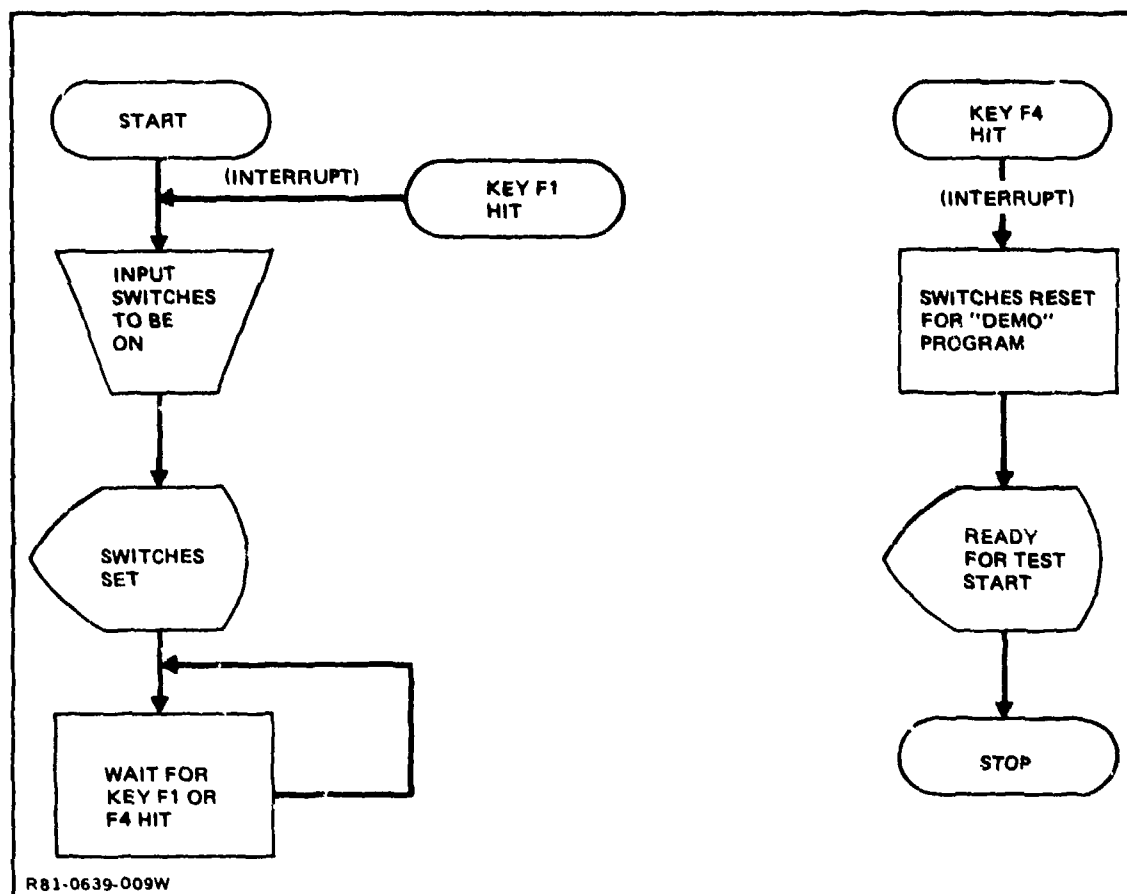


Fig. 2-38 SETUP Flowchart

Table 2-16 Program SETUP

```

00010 ON KEY 1 THEN GOSUB 80
00020 ON KEY 4 THEN GOSUB 340
00030 DIM A(16),B(16)
00040 INTEGER C ADDR $ECFE
00050 INTEGER Y
00060 GOSUB 80
00070 GO TO 70
00080 PRINT "INPUT THE NUMBER OF SWITCHES TO BE TURNED ON"
00090 INPUT N
00100 PRINT "INPUT THE SWITCHES YOU WANT ON"
00110 FOR I=1 TO N
00120 INPUT A(I)
00130 NEXT I
00140 FOR J=1 TO 16
00150 B(J)=J
00160 NEXT J
00170 FOR K=1 TO 16
00180 FOR I=1 TO N
00190 IF B(K)=A(I) THEN 220
00200 NEXT I
00210 B(K)=0
00220 NEXT K
00230 Y=0
00240 FOR I=1 TO 16
00250 IF B(I)=0 THEN 270
00260 Y=Y+2^(I-1)
00270 NEXT I
00280 PRINT Y
00290 PRINT "SWITCHES SET"
00300 PRINT "PUSH KEY F1 TO RESET"
00310 PRINT "PUSH KEY F4 TO TERMINATE SETUP PROGRAM"
00320 C=Y
00330 RETURN
00340 Y=$29
00350 C=Y
00360 PRINT CHR$(27); CHR$(66); "SWITCHES CONFIGURED FOR START OF TEST"
00370 PRINT CHR$(27); CHR$(66);
00380 STOP
00390 RETURN
00400 END

```

RA1-0638-05 W

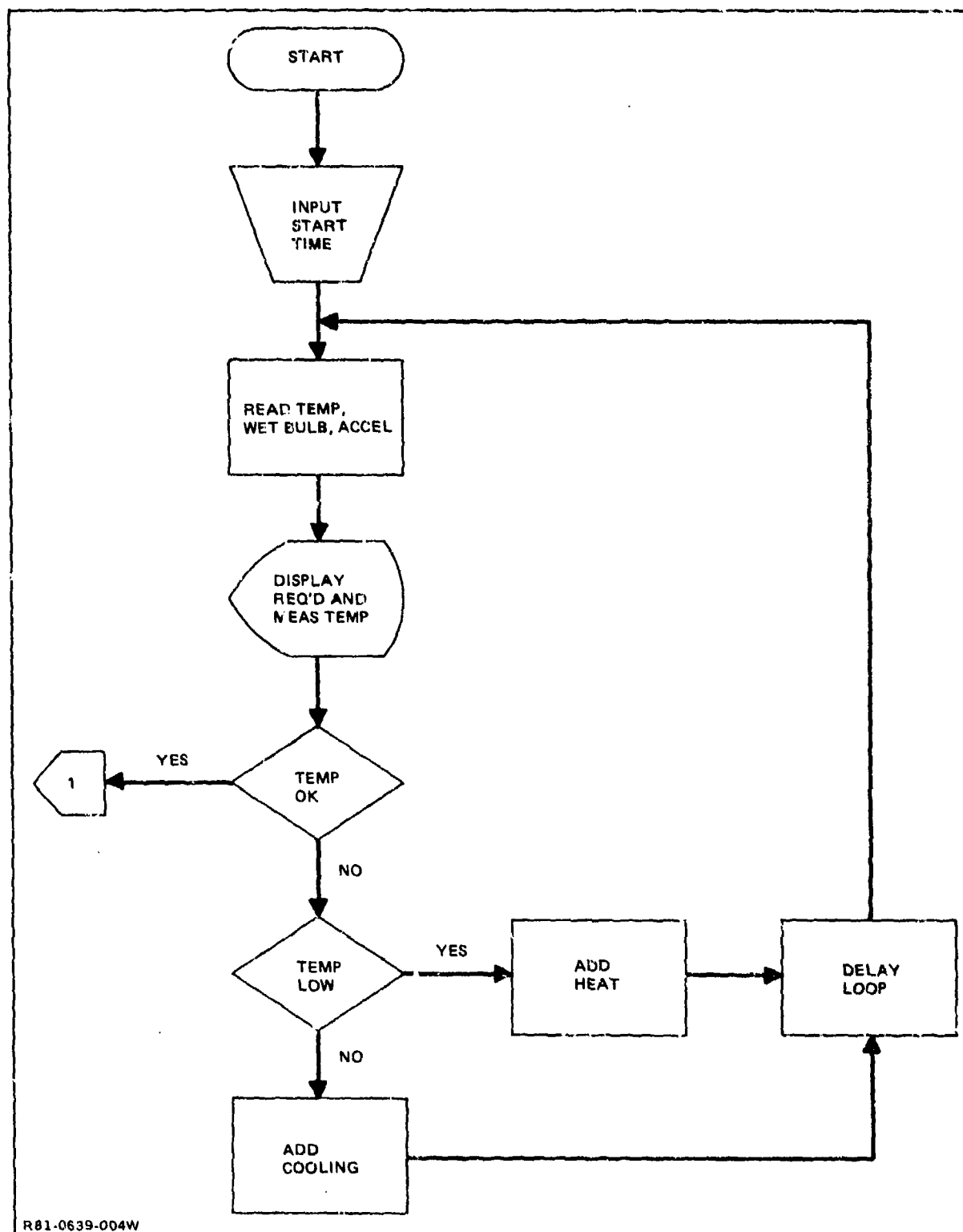


Fig. 2-39 DEMO Flowchart: Stabilization Routine

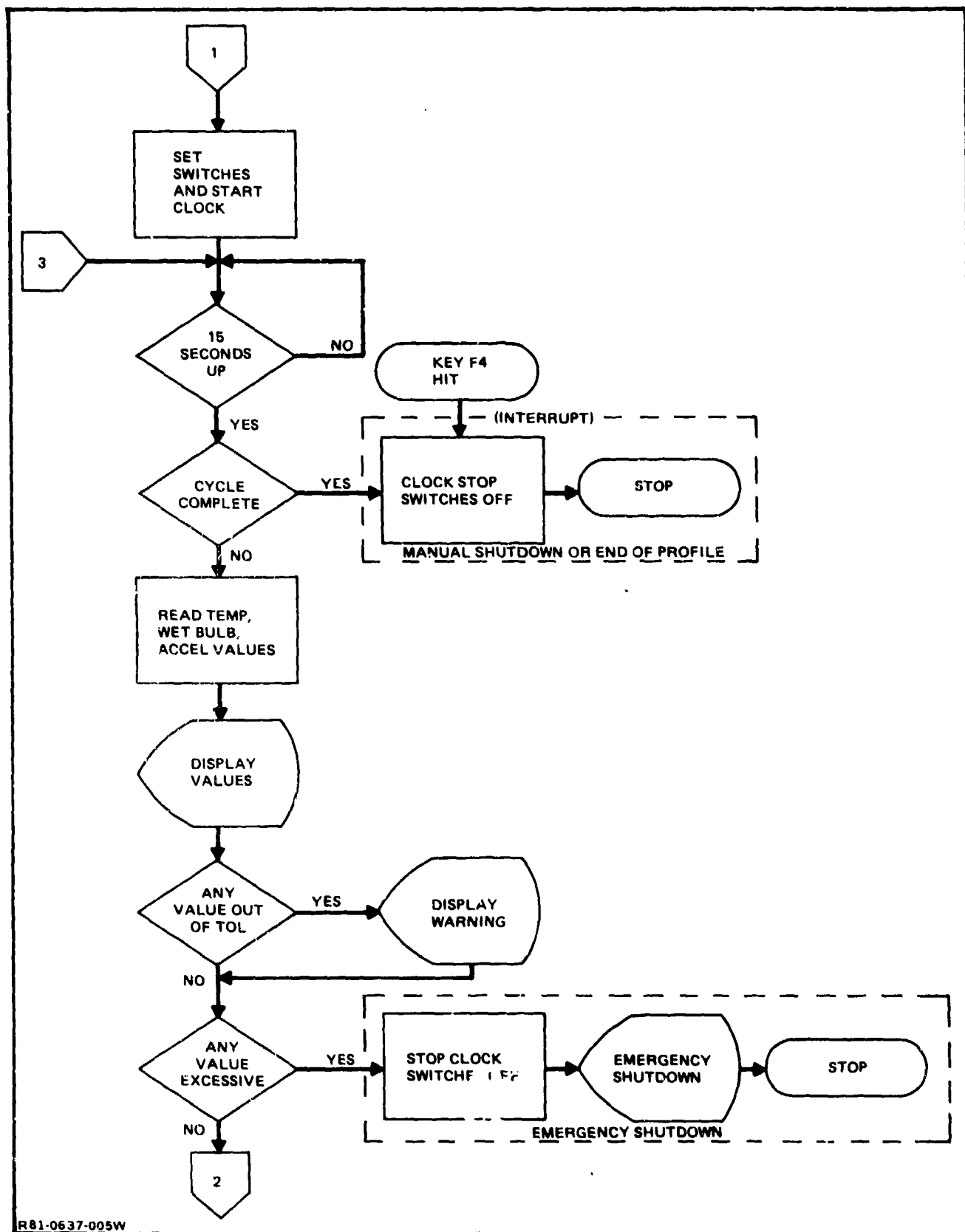


Fig. 2-40 DEMO Flowchart: Profile Monitor and Control

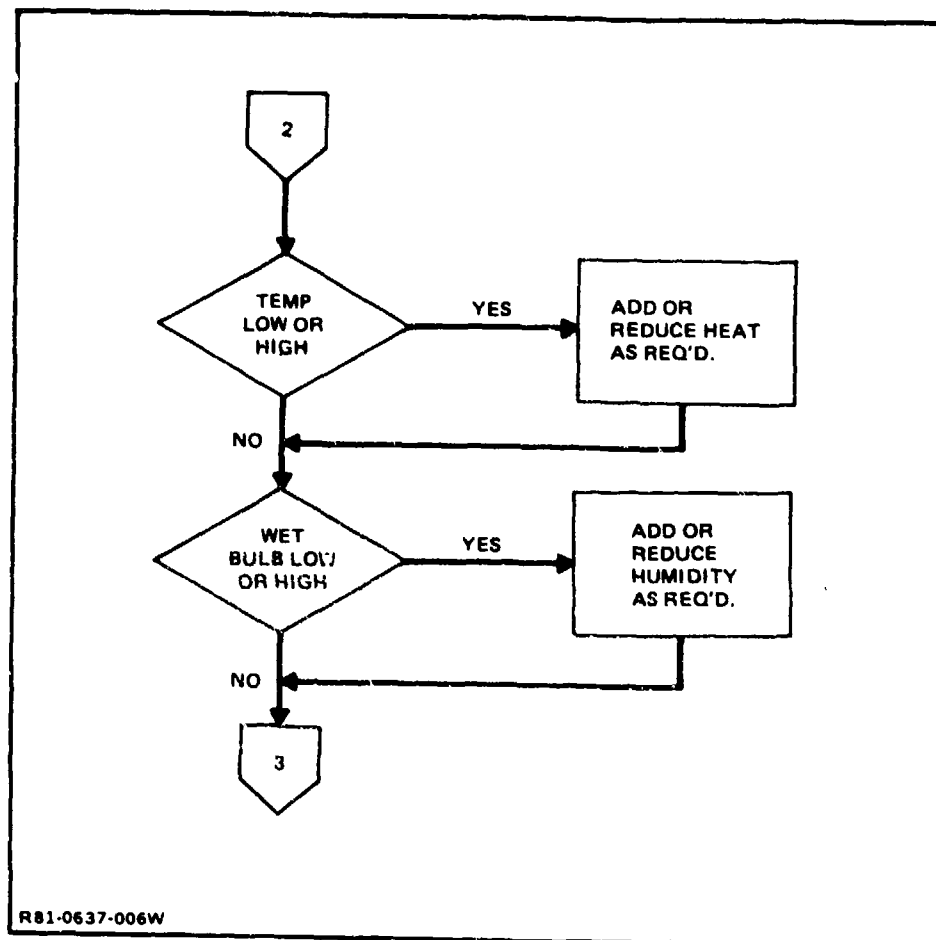


Fig. 2-41 DEMO Flowchart: Profile Monitor and Control (Cont.)

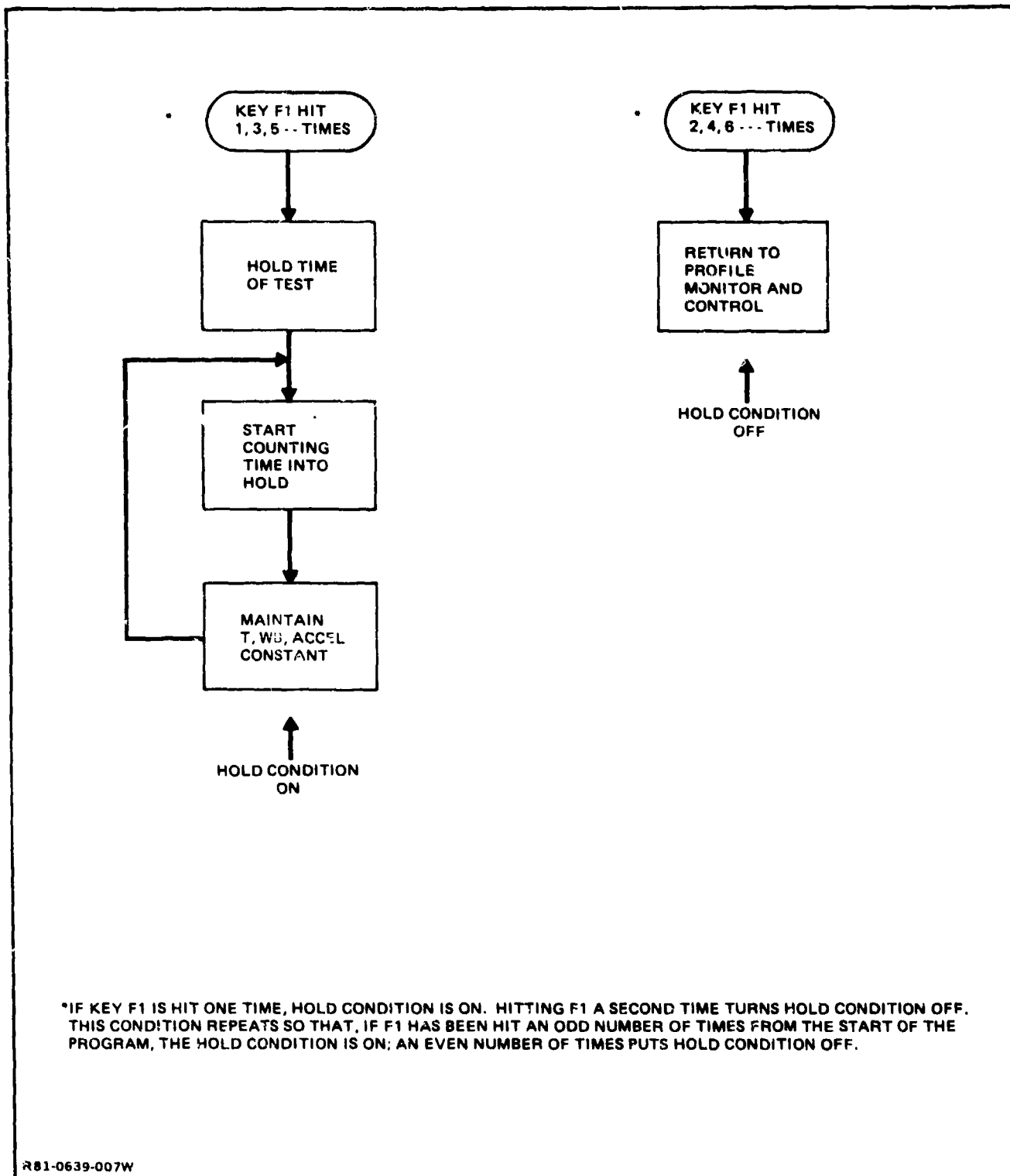


Fig. 2-42 DEMO Flowchart: Hold Routine

Table 2-17 Program DEMO

```

00010 ON KEY 1 THEN GOSUB 1130
00020 ON KEY 4 THEN GOSUB 1220
00030 INTEGER SWITCH ADDR $ECFE, TIME, TIK, S, HOLD, HOLD_TIME, ABT
00040 BYTE A1 ADDR $ED11
00050 INTEGER B1 ADDR $ED12
00060 DIM A(9,4)
00070 INTEGER B(9)
00080 READ T_T1, T_T2, T_T3, T_T4, WB_T1, WB_T2
00090 MAT READ A
00100 MAT READ B
00110 HOLD=$0
00120 PRINT "INPUT TIME IN MINUTES"
00130 INPUT TIME
00140 TIME=4*TIME
00150 GOSUB 760
00160 PRINT "TEMP="; TEMP, "TEMP REQD.="; T_R
00170 IF TEMP>T_R+T_T1 AND TEMP<=T_R+T_T2 THEN 230
00180 IF TEMP<T_R+T_T1 THEN SWITCH=$022B
00190 IF TEMP>T_R+T_T2 THEN SWITCH=$022D
00200 FOR I=1 TO 300
00210 NEXT I
00220 GO TO 150
00230 PRINT CHR$(17), "START", CHR$(7)
00240 GOSUB 1010
00250 BYTE CR13 ADDR $EF20
00260 BYTE CR2SR ADDR $EF21
00270 INTEGER TIMER3 ADDR $EF26
00280 ON NMI THEN GOSUB 300
00290 CR2SR=$1
00300 CR13=$1
00310 CR2SR=$0
00320 CR13=$43
00330 CR2SR=$1
00340 TIMER3=$F423
00350 CR13=$0
00360 TIK=$0
00370 GO TO 420
00380 TIK=TIK+$1
00390 CR2P=CR2SR
00400 TIME4=TIMER3
00410 RETURN
00420 IF TIK<=$1E THEN 370
00430 TIK=$0
00440 TIME=TIME+$1
00450 IF TIME=$04 THEN GOSUB 1220
00460 GOSUB 760
00470 PRINT
00480 PRINT "-----"
00490 IF HOLD=$0 THEN 550
00500 PRINT CHR$(27); CHR$(56); "SYSTEM IN HOLD - PUSH F1 TO RESUME TEST"
00510 PRINT "HOLD AT "; HOLD_TIME/4; " MINS"
00520 PRINT "HOLDING FOR "; TIME/4; " MINS"
00530 PRINT CHR$(27); CHR$(66);
00540 GO TO 560
00550 PRINT "TIME="; TIME/4
00560 PRINT
00570 PRINT "PARAMETER", "MEAS.", "REQUIRED"
00580 PRINT "ACCEL", ACCEL, A_R
00590 PRINT "WET_BULB", WET_BULB, WB_R
00600 PRINT "TEMP", TEMP, T_R
00610 PRINT
00620 IF ACCEL>=.9*A_R AND ACCEL<=1.1*A_R THEN 640
00630 PRINT CHR$(7), "ACCEL OUT"
00640 IF WET_BULB>WB_R+WB_T1 AND WET_BULB<=WB_R+WB_T2 THEN 660
00650 PRINT CHR$(7), "WET BULB OUT"

```

R81-0639-054(1/2)W

Table 2-17 Program DEMO (Contd)

```

00660 IF TEMP>T_R+T_T3 AND TEMP<=T_R+T_T4 THEN 680
00670 PRINT CHR$(7), "TEMPERATURE OUT"
00680 IF ACCEL>=4 OR TEMP<=-73 OR TEMP>=93 THEN 710
00690 GOSUB 1010
00700 GO TO 420
00710 SWITCH=$0201
00720 PRINT "EMERGENCY SHUTDOWN AT TIME="; TIME/4; " MINS."
00730 CR2SR=$0
00740 CR13=$0
00750 STOP
00760 A1=$0
00770 IF A1=$0 THEN 790
00780 GO TO 770
00790 TEMP=B1/64
00800 A1=$1
00810 IF A1=$1 THEN 830
00820 GO TO 810
00830 WET_BULB=B1/64
00840 A1=$8
00850 IF A1=$8 THEN 870
00860 GO TO 850
00870 ACCEL=(B1/32767)*80*(.1)
00880 ABT=TIME
00890 IF HOLD=$1 THEN TIME=HOLD_TIME
00900 FOR K=1 TO 8
00910 IF TIME>=A(K,1) AND TIME<A(K+1,1) THEN M=K
00920 NEXT K
00930 T_R=A(M,3)*(TIME/4)+A(M,4)
00940 A_R=A(M,2)
00950 IF TIME>=0 AND TIME<20 THEN WB_R=30
00960 IF TIME>=20 AND TIME<48 THEN WB_R=1.143*(TIME/4)+24.285
00970 IF TIME>=48 AND TIME<160 THEN WB_R=30
00980 IF TIME>=160 THEN WB_R=(-.6)*(TIME/4)+62
00990 TIME=ABT
01000 RETURN
01010 ABT=TIME
01020 IF HOLD=$1 THEN TIME=HOLD_TIME
01030 FOR LK=1 TO 8
01040 IF TIME>=A(LK,1) AND TIME<A(LK+1,1) THEN S=B(LK)
01050 NEXT LK
01060 IF TEMP<T_R+T_T1 THEN S=S+$2
01070 IF TEMP>T_R+T_T2 THEN S=S+$4
01080 IF WET_BULB<WB_R+1 THEN S=S+$10
01090 IF WET_BULB>WB_R+5 THEN S=S+$20000
01100 SWITCH=S
01110 TIME=ABT
01120 RETURN
01130 HOLD=ABS(HOLD-1)
01140 IF HOLD=1 THEN 1180
01150 TIME=HOLD_TIME
01160 PRINT "HOLD OFF - RESUME TEST"
01170 GO TO 1210
01180 HOLD_TIME=TIME
01190 PRINT "HOLD ON"
01200 TIME=$0
01210 RETURN
01220 SWITCH=$0200
01230 CR2SR=$0
01240 CR13=$0
01250 STOP
01260 RETURN
01270 DATA -1,1,-2,2,2,2,0,10
01280 DATA 0,1,17,0,37,20,2,34,5,12,48,2,34,0,71
01290 DATA 80,3,31,0,71,100,3,31,0,71,120,2,34,0,71
01300 DATA 140,1,17,0,71,160,1,17,-5,271,180,0,0,46
01310 DATA $0329,$0BE9,$0BE9,$13E9,$1329,$0BE9,$0329,$0329,$0200

```

R81-0639-054(2/2)W

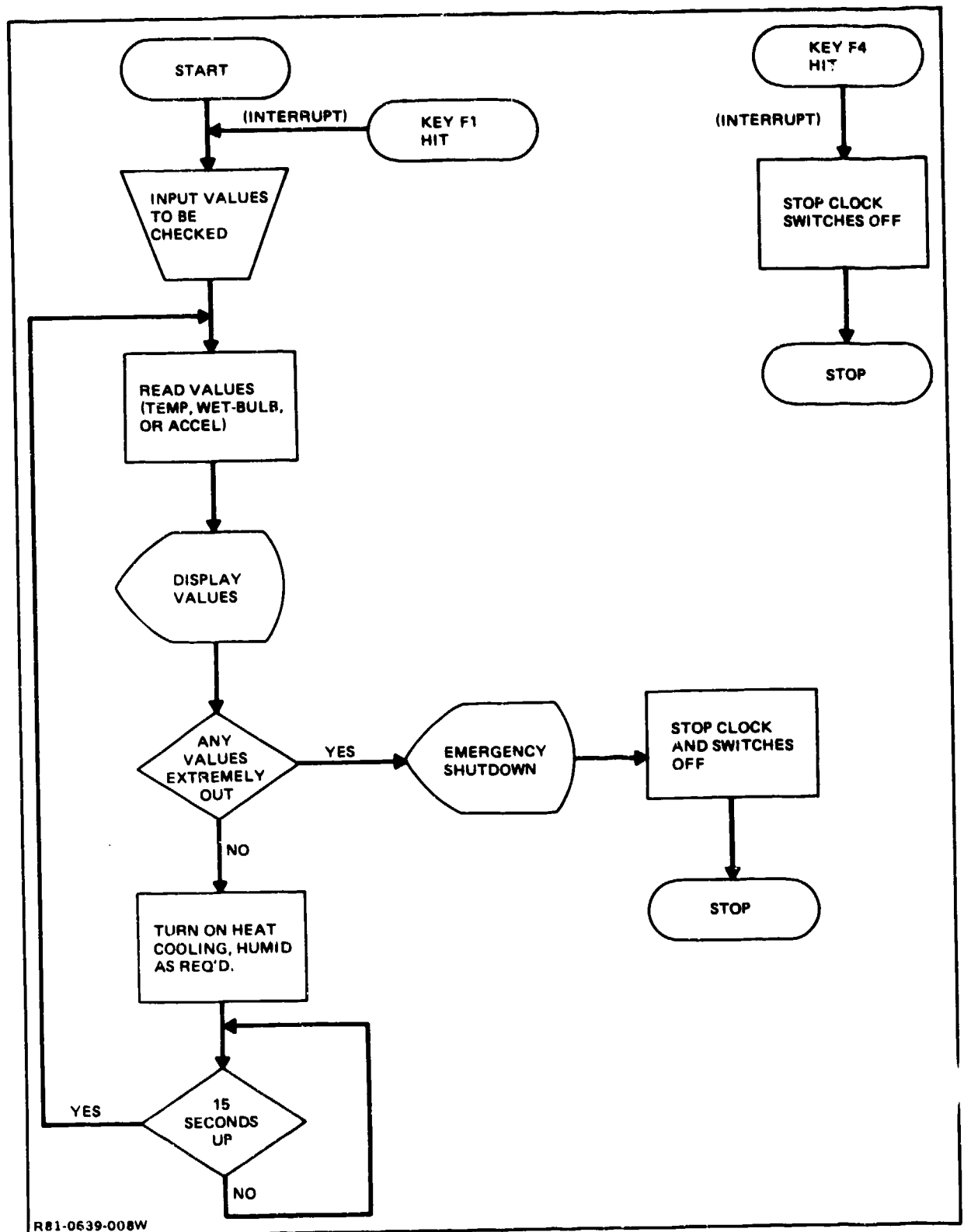


Fig. 2-43 TROUBLESHOOT Flowchart

Table 2-18 Program TROUBLESHOOT

```

00010 ON KEY 1 THEN GOSUB 940
00020 ON KEY 4 THEN GOSUB 1000
00030 INTEGER SWITCH ADDR $ECFE, TIME, TIK, S, T, H, U, TA
00040 BYTE A1 ADDR $ED11
00050 INTEGER B1 ADDR $ED12
00060 READ T_T1, T_T2, T_T3, T_T4, WB_T1, WB_T2
00070 SWITCH=$0221
00080 PRINT
00090 PRINT "DO YOU WANT TEMP? (YES=1, NO=0)"
00100 INPUT T
00110 IF T=$0 THEN 140
00120 PRINT "WHAT TEMPERATURE VALUE? - IN DEGREES CENTIGRADE"
00130 INPUT T_R
00140 PRINT "DO YOU WANT VIBRATION? (YES=1, NO=0)"
00150 INPUT U
00160 IF U=$0 THEN 190
00170 PRINT "WHAT G LEVEL?"
00180 INPUT A_R
00190 PRINT "DO YOU WANT HUMIDITY? (YES=1, NO=0)"
00200 INPUT H
00210 IF H=$0 THEN 240
00220 PRINT "WHAT WET BULB TEMPERATURE? - IN DEGREES CENTIGRADE"
00230 INPUT WB_R
00240 PRINT "DO YOU WANT THE TEST ARTICLE POWER ON? (YES=1, NO=0)"
00250 INPUT TA
00255 TIME=$0
00260 PRINT CHR$(17); "START TROUBLE-SHOOTING"; CHR$(7)
00265 GOSUB 640
00270 GOSUB 795
00280 BYTE CR13 ADDR JEF20
00290 BYTE CR2SR ADDR $EF21
00300 INTEGER TIMER3 ADDR $EF26
00310 ON NMI THEN GOSUB 400
00320 CR2SR=$1
00330 CR13=$1
00340 CR2SR=$0
00350 CR13=$43
00360 CR2SR=$1
00370 TIMER3=$F423
00380 CR13=$0
00390 TIK=$0
00400 GO TO 440
00410 TIK=TIK+$1
00420 CR2P=CR2SR
00430 TIME4=TIMER3
00440 RETURN
00450 IF TIK<$1E THEN 390
00460 TIK=$0
00470 TIME=TIME+$1
00480 GOSUB 640
00490 PRINT "-----"
00500 PRINT "TIME=", TIME/4, " MINUTES"
00510 IF T=$0 THEN 510
00520 PRINT "ACTUAL TEMP= ", TEMP, " REQ'D TEMP= ", T_R
00530 IF TEMP>T_R+T_T3 AND TEMP<=T_R+T_T4 THEN 510
00540 PRINT CHR$(7); "TEMP OUT"
00550 IF H=$0 THEN 530
00560 PRINT "ACTUAL WET BULB TEMP= ", WB_T1, " REQ'D WET BULB TEMP= "
00570 IF WB_T1=WB_R+WB_T1 AND WB_T1<=WB_R+WB_T2 THEN 530
00580 PRINT CHR$(7); "WET BULB OUT"
00590 IF U=$0 THEN 555
00600 PRINT "VIBRATION LEVEL IS ", ACCEL, " REQ'D LEVEL IS ", A_R
00610 IF ACCEL>= 9*A_R AND ACCEL<=1.1*A_R THEN 555
00620 PRINT CHR$(7); "ACCEL OUT"

```

R81-0639-055(1/2)W

Table 2-18 Program TROUBLESHOOT (Contd)

```

00557 IF ACCEL>=4 THEN 590
00558 IF T=$0 THEN 570
00559 IF TEMP<=-73 OR TEMP>=93 THEN 590
00560 GOSUB 795
00561 GO TO 440
00562 SWITCH=$0221
00563 PRINT "EMERGENCY SHUTDOWN!"
00564 CR2SR=$0
00565 CR13=$0
00566 STOP
00567 IF T=$0 THEN 690
00568 A1=$0
00569 IF A1=$0 THEN 690
00570 GO TO 660
00571 TEMP=S1/64
00572 IF H=$0 THEN 740
00573 A1=$1
00574 IF A1=$1 THEN 730
00575 GO TO 710
00576 WET_BULB=S1/64
00577 IF U=$0 THEN 790
00578 A1=$8
00579 IF A1=$8 THEN 780
00580 GO TO 760
00581 ACCEL=(S1/32767)*80*(.1)
00582 RETURN
00583 S=$0221
00584 IF T=$0 THEN 830
00585 IF TEMP<T_R+T_T1 THEN S=S+$2
00586 IF TEMP>T_R+T_T2 THEN S=S+$4
00587 IF H=$0 THEN 860
00588 S=S+$8
00589 IF WET_BULB<WB_R+1 THEN S=S+$10
00590 IF WET_BULB>WB_R+5 THEN S=S+$2000
00591 IF U=$0 THEN 900
00592 IF A_R>=1 AND A_R<=2 THEN S=S+$0100
00593 IF A_R>2 AND A_R<=3 THEN S=S+$0900
00594 IF A_R>3 THEN S=S+$1100
00595 IF TA=$0 THEN 920
00596 S=S+$C0
00597 PRINT "TEST ARTICLE POWER IS ON."
00598 PRINT
00599 SWITCH=S
00600 RETURN
00601 PRINT "RESTART TROUBLESHOOTING PROCEDURE"
00602 CR2SR=$0
00603 CR13=$0
00604 GO TO 70
00605 RETURN
00606 PRINT "PROCEDURE TERMINATED"
00607 SWITCH=$0200
00608 CR2SR=$0
00609 CR13=$0
00610 STOP
00611 RETURN
00612 DATA -1,1,-2,2,2,2,0,10

```

R81-0639-055(2/2)W

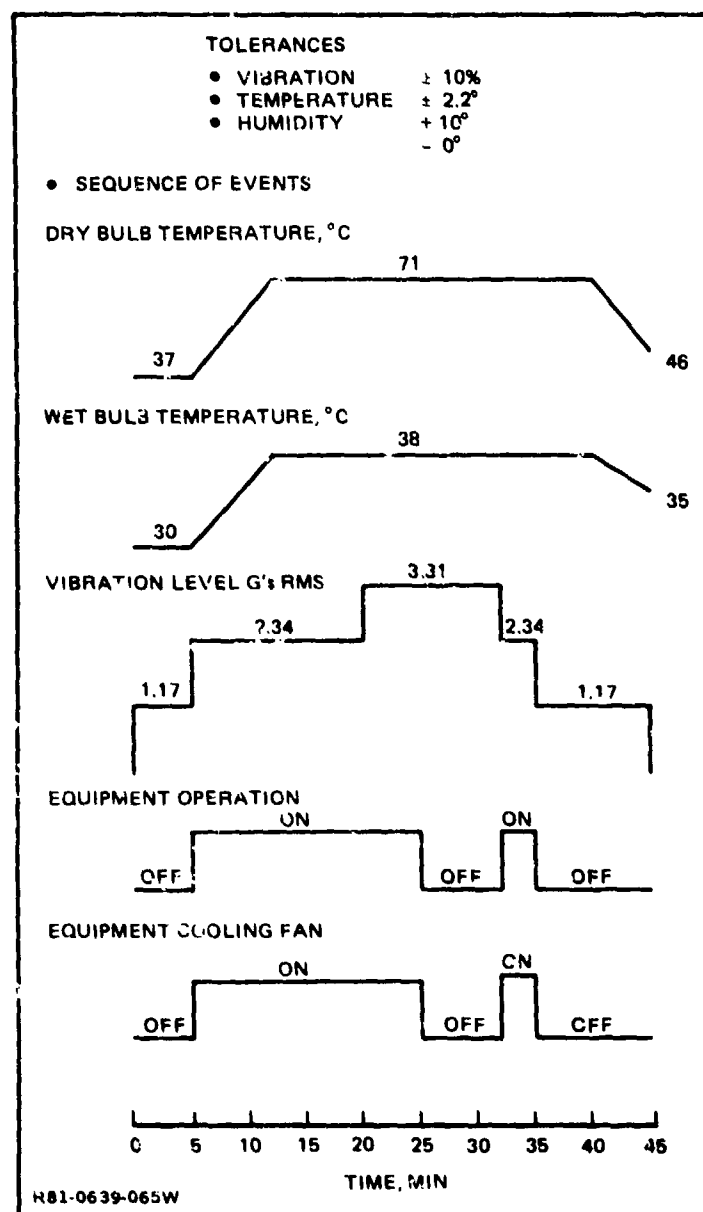


Fig. 2-44 Demonstration of Microprocessor Tape System

Table 2-19 Microprocessor Control System Printout

TIME=12.5		
PARAMETER	MEAS.	REQUIRED
ACCEL	2.20075076	2.34
WET BULB	42.796875	38
TEMP	69.328125	71

TIME=13.75		
PARAMETER	MEAS.	REQUIRED
ACCEL	2.32892849	2.34
WET BULB	42.78125	38
TEMP	69.828125	71

TIME=14		
PARAMETER	MEAS.	REQUIRED
ACCEL	2.28792679	2.34
WET BULB	42.984375	38
TEMP	69.747125	71

R81-0639-051W		

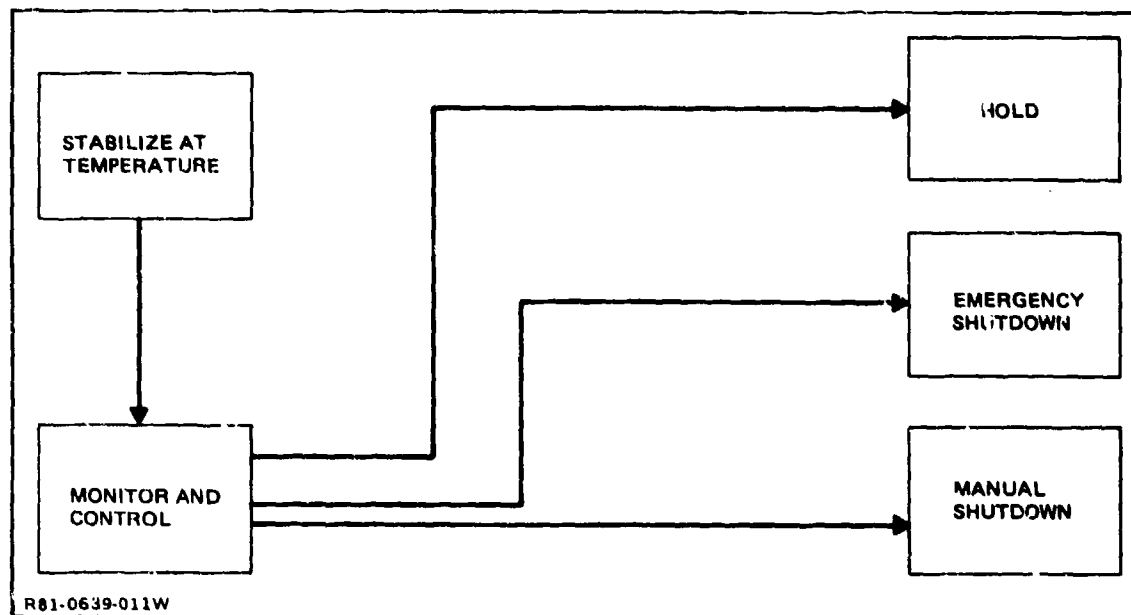


Fig. 2-45 Microprocessor Demonstration Program

Once readings have been taken and displayed, control of the program is transferred to a switching subroutine, lines 1020 to 1120. In the subroutine, decisions on activating switches are made based on the profile time and out of tolerance conditions.

Depressing key F4 transfers control to a subroutine which stops the clock and terminates the program, lines 1220 to 1250.

Depressing key F1 puts the program on the hold condition by transferring control to a subroutine at lines 1130 to 1210. The hold condition halts the time of the test. Temperature and vibration levels are held constant to the values required prior to entering the hold condition. While in the hold condition, the monitor and control portion of the program is repeated. However, all calculated parameters are based on the constant time point when the hold condition was initiated.

Depressing key F1 again terminates the hold condition. The program resumes monitoring and controlling the test profile.

Lines 1270 through 1310 are data statements that define the temperature tolerances and test profiles. Tolerances are given in line 1270 as follows:

- $\pm 1^{\circ}\text{C}$ will initiate chamber heating or cooling
- $\pm 2.2^{\circ}\text{C}$ will issue a dry bulb temperature out of tolerance warning
- -0° , $+10^{\circ}\text{C}$ will issue a wet bulb temperature out of tolerance warning.

Lines 1280 to 1300 are values that define the accelerometer and temperature profile. These are input as a 4-column matrix that represents straight line segments of the profiles. The first column lists the starting times of each segment. The second column is the required acceleration level, and columns 3 and 4 are the slope and intercept of the dry bulb temperature. Line 1310 lists hexadecimal constants which, when read into memory, activate various switches at the times prescribed in column 1 of the matrix. Each time point given represents the number of 15-second intervals.

Humidity control is provided in lines 1080 and 1090. A wet bulb temperature reading less than the required value plus 1°C activates the chamber humidifier.

A reading greater than the required value plus 5°C activates the dehumidifier. Acceleration out of tolerance conditions occur for a $\pm 10\%$ deviation in rms g level, line 620.

2.4.4.4 "TROUBLESHOOT" - The TROUBLESHOOT program permits the user to monitor and control four parameters in any sequence. The parameters are dry bulb temperature, wet bulb temperature, acceleration and test article activation. The program differs from DEMO since no profile is monitored or controlled. The program will monitor and control wet bulb or dry bulb temperature to a constant value input by the operator. It will maintain vibration to any of three prescribed values: 1.17, 2.34 or 3.31 g rms. Table 2-20 lists the various segments of the program by line number and the function each performs. Depressing key F1 restarts the program and depressing key F4 terminates the program.

2.4.4.5 "RELDEM" - The DEMO program was written to monitor and control the test facility for a cycle of 45 minutes duration. It was modified to monitor and control the facility for an eight-hour cycle. The modified program was named RELDEM, and the acceleration and thermal profiles written into the program are presented in Figure 2-2. A listing of the program is presented in Table 2-21. The flowchart for DEMO can be used to follow the program logic for RELDEM.

Although RELDEM and DEMO are similar, changes were incorporated to reflect the different test profiles. These changes are as follows:

- Data statements, lines 1280 to 1380, have been modified to represent the new profiles.
- Times have been modified to account for an eight-hour cycle time, line 450.
- Additional statements have been added to monitor and control the humidity over a small portion of the test cycle. (DEMO measured and controlled humidity during the entire 45-minute cycle.) These changes were incorporated in lines 585, 635, 795, 945 and 1075.

2.4.4.6 Random Noise Programming - The random noise spectrum required for the reliability demonstration test is shown in Figure 2-1. Using the temperature-compensated sine transfer characteristics measured for the system (see Para. 2.3.4), and measured tape recorder characteristics (see Para. 2.4.2), a

Table 2-20 TROUBLESHOOT Program Segments

LINE NUMBERS	FUNCTION
90 - 250	INPUT PARAMETERS DESIRED AND TO WHAT VALUE THEY SHOULD BE HELD.
270 - 460	START THE MICROPROCESSOR CLOCK. AS IN DEMO THE CLOCK WORKS ON A ONE HALF SECOND INTERRUPT. SIXTY COUNTS OF THE INTERRUPT YIELDS A PRINTOUT EVERY 15 SECONDS.
480 - 560	PROVIDES PRINTOUT AND CHECK FOR OUT OF TOLERANCE CONDITIONS.
590 - 630	EMERGENCY SHUTDOWN PROCEDURE AS IN DEMO.
640 - 790	TEMPERATURE AND ACCELERATIONS ARE READ IN.
795 - 930	SWITCHES ARE ACTIVATED TO CONTROL THE VALUES AS REQUIRED.
R81-0639-049W	

Table 2-21 Program RELDEM

```

00010 ON KEY 1 THEN GOSUB 1130
00020 ON KEY 4 THEN GOSUB 1220
00030 INTEGER SWITCH ADDR $ECFE, TIME, TIK, S, HOLD_TIME, ABT
00040 BYTE A1 ADDR $ED11
00050 INTEGER B1 ADDR $ED12
00060 DIM A(23,4)
00070 INTEGER B(18,2)
00080 READ T_T1, T_T2, T_T3, T_T4, WB_T1, WB_T2
00090 MAT READ A
00100 MAT READ B
00110 HOLD=$0
00120 PRINT "INPUT TIME IN MINUTES"
00130 INPUT TIME
00140 TIME=4*TIME
00150 GOSUB 760
00160 PRINT "TEMP="; TEMP, "TEMP REQD.="; T_R
00170 IF TEMP>T_R+T_T1 AND TEMP<=T_R+T_T2 THEN 230
00180 IF TEMP<T_R+T_T1 THEN SWITCH=$23
00190 IF TEMP>T_R+T_T2 THEN SWITCH=$25
00200 FOR I=1 TO 200
00210 NEXT I
00220 GO TO 150
00230 PRINT CHR$(17), "START", CHR$(7)
00240 GOSUB 1010
00250 BYTE CR13 ADDR $EF20
00260 BYTE CR2SR ADDR $EF21
00270 INTEGER TIMER3 ADDR $EF26
00280 ON NMI THEN GOSUB 300
00290 CR2SR=$1
00300 CR13=$1
00310 CR2SR=$0
00320 CR13=$43
00330 CR2SR=$1
00340 TIMER3=$F423
00350 CR13=$0
00360 TIK=$0
00370 GO TO 420
00380 TIK=TIK+$1
00390 CR2P=CR2SR
00400 TIME4=TIMER3
00410 RETURN
00420 IF TIK<$1E THEN 370
00430 TIK=$0
00440 TIME=TIME+$1
00450 IF TIME=$0780 THEN GOSUB 1220
00460 GOSUB 760
00470 PRINT
00480 PRINT "-----"
00490 IF HOLD=$0 THEN 550
00500 PRINT CHR$(27); CHR$(66); "SYSTEM IN HOLD - PUSH F1 TO RESUME TEST"
00510 PRINT "HOLD AT "; HOLD_TIME/4; " MINS"
00520 PRINT "HOLDING FOR "; TIME/4; " MINS"
00530 PRINT CHR$(27); CHR$(66);
00540 GO TO 560
00550 PRINT "TIME="; TIME/4
00560 PRINT

```

R81-0639-063(1/3)W

Table 2-21 Program RELDEM (Contd)

```

00570 PRINT "PARAMETER", "MEAS.", "REQUIRED"
00580 PRINT "ACCEL", ACCEL, A_R
00585 IF TIME<$0398 OR TIME>$0480 THEN 600
00590 PRINT "WET BULB", WET_BULB, WB_R
00600 PRINT "TEMP", TEMP, T_R
00610 PRINT
00620 IF ACCEL>=.9*A_R AND ACCEL<=1.1*A_R THEN 640
00630 PRINT CHR$(7), "ACCEL OUT"
00635 IF TIME<$0398 OR TIME>$0480 THEN 660
00640 IF WET_BULB>WB_R+WB_T1 AND WET_BULB<=WB_R+WB_T2 THEN 660
00650 PRINT CHR$(7), "WET BULB OUT"
00660 IF TEMP>T_R+T_T3 AND TEMP<=T_R+T_T4 THEN 680
00670 PRINT CHR$(7), "TEMPERATURE OUT"
00680 IF ACCEL>=4 OR TEMP<=-73 OR TEMP>=93 THEN 710
00690 GOSUB 1010
00700 GO TO 420
00710 SWITCH=$0201
00720 PRINT "EMERGENCY SHUTDOWN AT TIME="; TIME/4; " MINS."
00730 CR2SR=$8
00740 CR13=$8
00750 STOP
00760 A1=$0
00770 IF A1=$0 THEN 790
00780 GO TO 770
00790 TEMP=B1/64
00795 IF TIME<$0398 OR TIME>$0480 THEN 840
00800 A1=$1
00810 IF A1=$1 THEN 830
00820 GO TO 810
00830 WET_BULB=B1/64
00840 A1=$8
00850 IF A1=$8 THEN 870
00860 GO TO 850
00870 ACCEL=(B1/32767)*80*(.1)
00880 ABT=TIME
00890 IF HOLD=$1 THEN TIME=HOLD_TIME
00900 FOR K=1 TO 22
00910 IF TIME>=A(K,1) AND TIME<A(K+1,1) THEN M=K
00920 NEXT K
00930 T_R=A(M,3)*(TIME/4)+A(M,4)
00940 A_R=A(M,2)
00945 IF TIME<$0398 OR TIME>$0480 THEN 990
00950 IF TIME>920 AND TIME<960 THEN WB_R=3.8*(TIME/4)-874
00960 IF TIME>=960 THEN WB_R=38
00970 IF TIME>=48 AND TIME<160 THEN WB_R=38
00980 IF TIME>=160 THEN WB_R=(-.6)*(TIME/4)+62
00990 TIME=ABT
01000 RETURN
01010 ABT=TIME
01020 IF HOLD=$1 THEN TIME=HOLD_TIME
01030 FOR LK=1 TO 17
01040 IF TIME>=B(LK,1) AND TIME<B(LK+1,1) THEN M=LK
01050 NEXT LK
01055 S=B(M,2)
01060 IF TEMP<T_R+T_T1 THEN S=S+$2
01070 IF TEMP>T_R+T_T2 THEN S=S+$4

```

R81-0639-063(2/3)W

Table 2-21 Program REIDEM (Contd)

```

01075 IF TIME<$0398 OR TIME>$0400 THEN 1100
01080 IF WET_BULB<WB_R+1 THEN S=S+$10
01090 IF WET_BULB>WB_R+5 THEN S=S+$2000
01100 SWITCH=S
01110 TIME=ABT
01120 RETURN
01130 HOLD=ABS(HOLD-1)
01140 IF HOLD=1 THEN 1180
01150 TIME=HOLD_TIME
01160 PRINT "HOLD OFF - RESUME TEST"
01170 GO TO 1210
01180 HOLD_TIME=TIME
01190 PRINT "HOLD ON"
01200 TIME=$0
01205 ON KEY 1 THEN GOSUB 1130
01210 RETURN
01220 SWITCH=$0200
01230 CR2SR=$0
01240 CR13=$0
01250 STOP
01260 RETURN
01270 DATA -1,1,-2,2,2,2,0,10
01280 DATA 0,0,0,-54,240,1.83,5,-354,240,1.17,5,-354
01290 DATA 264,1.17,0,-26,500,2.34,5,-651,512,2.34,0,-10
01300 DATA 560,3.31,0,-10,600,2.34,-5,749,620,1.17,0,-26
01310 DATA 884,1.17,5,-1129,960,0,0,71,1200,1.83,-5,1571
01320 DATA 1208,1.17,-5,1571,1220,1.17,0,37,1480,2.34,5,-1813
01330 DATA 1500,2.34,0,71,1540,3.31,0,71,1580,2.34,0,71
01340 DATA 1600,1.17,0,71,1620,1.17,-5,2096,1660,1.17,0,10
01350 DATA 1868,1.17,-5,2346,1920,1.17,0,-34
01360 DATA 0,$21,120,$E1,240,$05E1,240,$01E1,500,$09E1,560,$11E1
01370 DATA 600,$09E1,620,$01E1,900,$01E9,960,$29,1000,$E9,1200,$05E1
01380 DATA 1208,$01E1,1480,$09E1,1540,$11E1,1580,$09E1,1600,$01E1,1920,$2

```

1
R81-0639-063(3/3)W

synthetic random noise spectrum was calculated for the required test spectrum. The calculations and recording method used are essentially the same as for the Multiplex system as described in Para. 2.3.4.

However, because the microprocessor was programmed to switch the test levels (see para. 2.4.4), the synthetic random voltage was recorded at a single test level on the tape cartridge. Figure 2-46 shows a spectrum analysis of the synthetic random voltage recorded on the tape.

2.4.5 System Operation

Since the microprocessor system became operational in the second phase of the program, most of the test runs were made using the short demonstration tape. This facilitated program debugging while exercising all program functions. While the preceding section discussed mainly the software, this section will explain how the software programs were set up and run in the laboratory, problems that were found, and corrections that were made in the test programs.

2.4.5.1 System Setup - The initial step in operating the system is to turn on the power to the computer, exciter system, and temperature chamber. At turn-on, however, the microprocessor turns on the control relays in a random fashion. This can activate the chamber heater or cooler and cause an uncontrolled temperature change. To preclude this potential problem, the first step before turn-on of the temperature chamber must be to initialize the status of all control relays to zero (OFF). This is accomplished by typing two instructions into the terminal as specified in the procedure (App. B)

is inserted into the left disk drive of the microprocessor as shown in Figure 2-47.

The first program that is loaded into the computer is the CALIBRATE program. This is used to apply calibration voltages to the three input data channels and verify linearity and correct readout in the display. As pointed out in the previous section, the acceleration channel must be calibrated with a random noise source using a true-RMS meter as a reference. This can be accomplished by running the tape through the shaker system and adjusting the gain pot on the A-D board for the accelerometer channel so that the CRT display reads the same as the true-RMS meter. The existing calibration program requires manually setting the control relays for vibration by typing enable codes into the switch addresses.

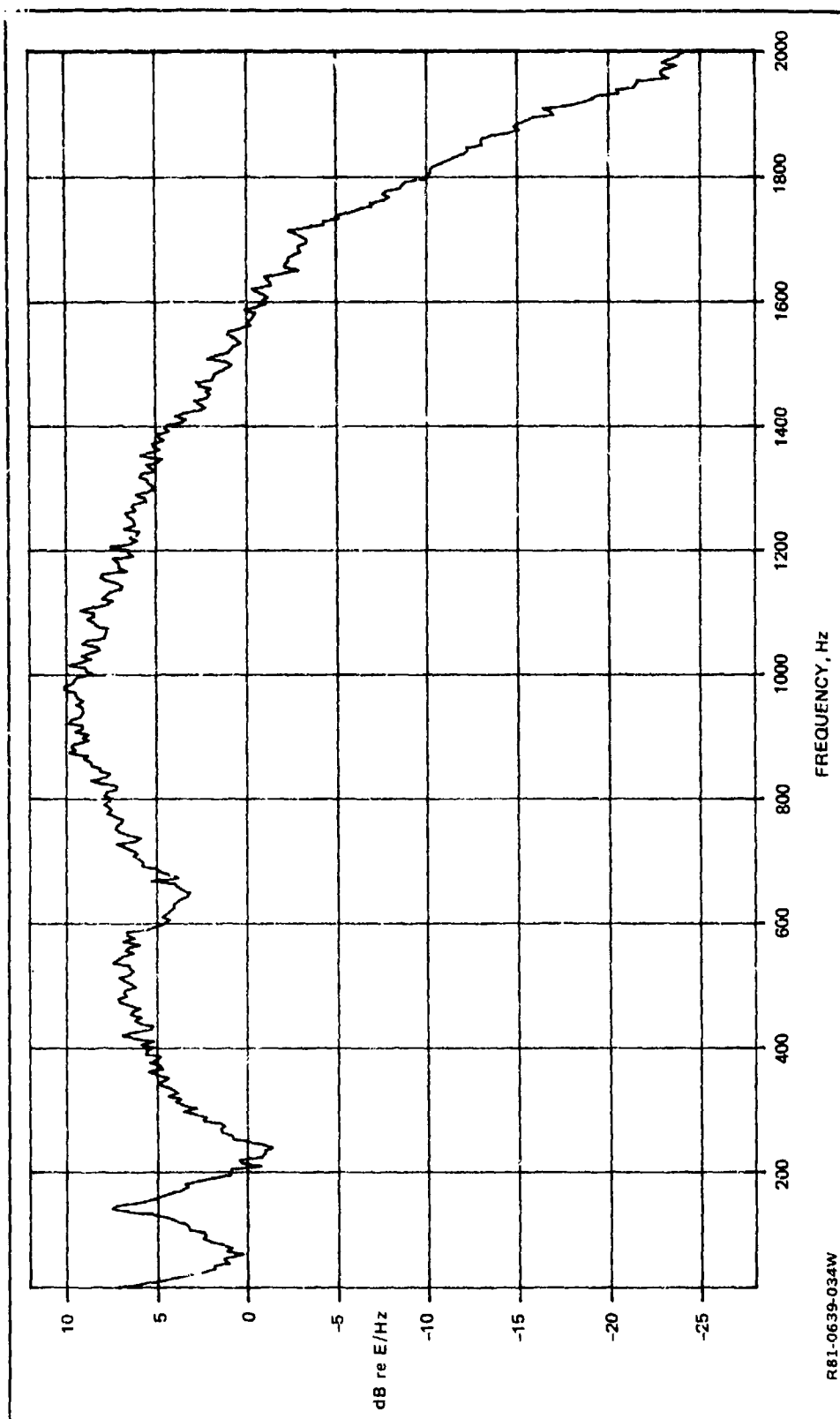


Fig. 2-46 Microprocessor System: Recorded Random Voltage, Temperature Compensated



R81-0639-068W

Fig. 2-47 Inserting Program Disk in Microprocessor

At the conclusion of the "calibrate" mode, the SETUP program is loaded in the microprocessor. This program is used to set the shaker level to the required 0 dB level (3.31 G rms) with the vibration control relay set for 0 dB. With the tape recorder running and the control relays set by the program (relay 6, 9 and 13 set to ON), shaker gain is adjusted until the required 0 dB level 3.13 G rms) is read on the true-RMS meter.

The data readings were checked against calibrated sources and no significant discrepancies were found. Linearity was good over the range of the test. It is, however, recommended that the CALIBRATE and SETUP programs be merged into one so that the accelerometer channel can be calibrated at the same time that the shaker gain is set.

2.4.5.2 Running Reliability Demonstration Programs - During the initial test runs with the reliability demonstration program, it was found that the temperature of the chamber cycled excessively around the reference level. The initial program called for the temperature to be sampled once a minute, compared to the reference, and control action taken (heater or cooler turned on). The control cycle was changed to 20 seconds and then to 15 seconds. The 15 second control cycle provided excellent temperature control without excessive cycling or overshoot during transition. (The time of the control cycle is a function of the chamber characteristics and must be optimized for each test chamber.)

Another problem encountered during initial test runs were with random electrical transients (picked up by the thermocouple or accelerometer lines) from shutting down the test due to over-temperature or over-acceleration test abort limits. The program was therefore modified to require the average of two consecutive readings exceeding the abort limit to cause shutdown. This cured the transient shutdown problem but still provided system safety since an abrupt major change in test levels is improbable. Gradual changes will cause alarm signals denoting a test tolerance has been exceeded, to alert the test operator well in advance of emergency shutdown.

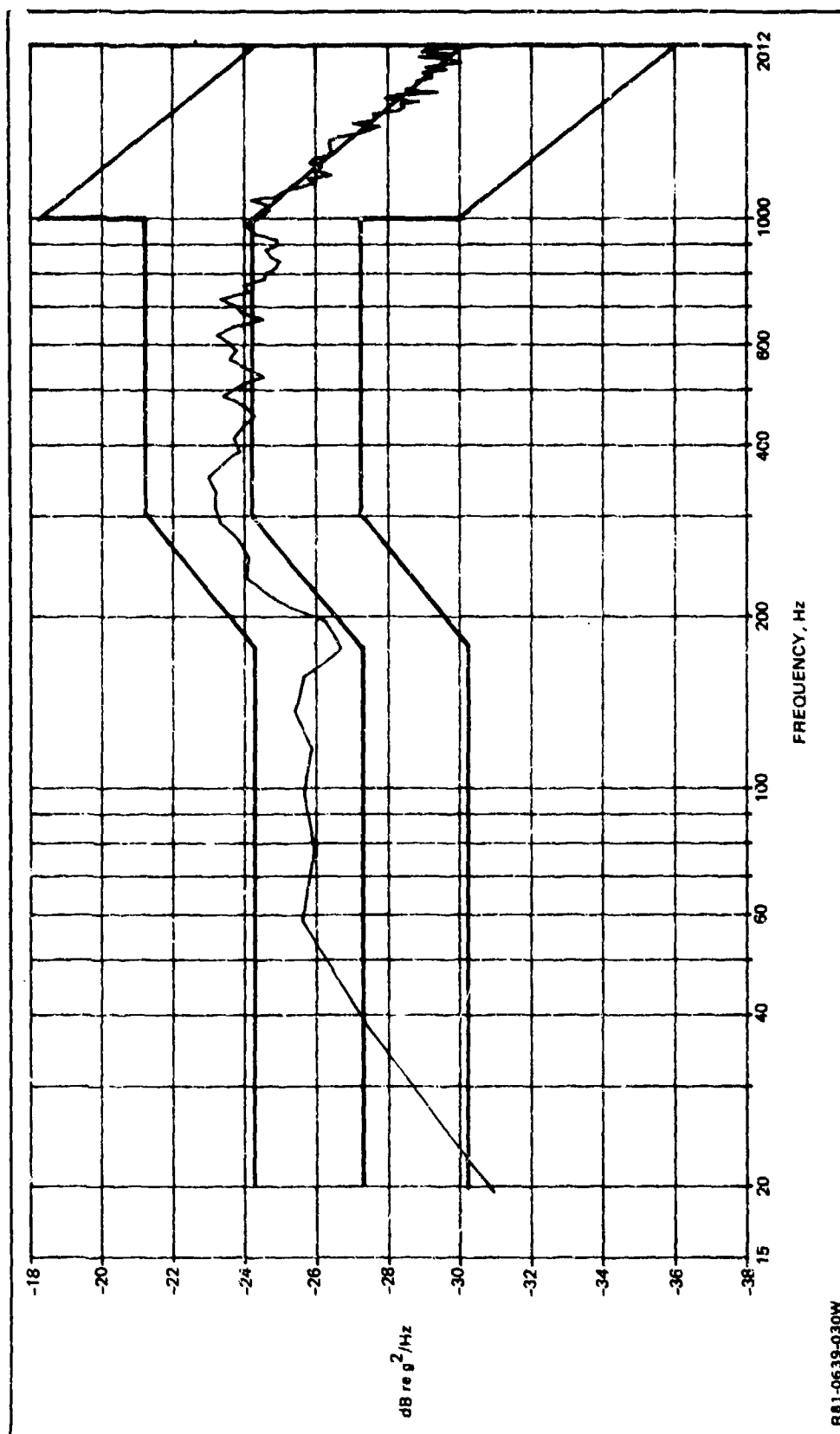
Also with regard to emergency shutdown, mention should be made of some of the unique characteristics of the random vibration tape deck. One feature of

the "endless loop" cartridge is that, in every 12-minute cycle, it has two breaks in the random signal of about 1-second duration. The first at the tape splice forming the loop, and the second where the recording of the synthetic random voltage was terminated. This results in a momentary vibration interruption to the test article, indicated by a slight drop in the acceleration level. These short-duration interruptions, while audibly detectable, do not affect the computer program or test integrity.

The more important feature with regard to emergency shutdown of the vibration system is the use of the second tape channel to record the control accelerometer. As described previously, the left channel of the tape deck is in the playback mode and supplies the random signal to drive the exciter. The right channel of the tape deck is in the record mode and is used to record the control accelerometer. Because of the 12-minute duration of the loop, the right channel is continuously erasing old data and recording new data. Thus it always has a recording of the last 12 minutes of the test. When an emergency dump of the exciter system occurs due to an over-test condition, the tape deck drive will be halted immediately. The right channel contains an acceleration time history of the last 12 minutes of the test. This can be analyzed to determine the spectral changes causing the shutdown.

The right channel data can also be used for periodic playback of the control accelerometer for spectrum verification. Figure 2-48 shows a typical spectrum verification made by playing the right channel tape through the H/P 5427A spectrum analyzer. The plot shows a gradual drop in the test level below 70 Hz, that is due to the frequency characteristics of the tape deck which have not been compensated for during playback. If we again play the tape back through the H/P 5427A spectrum analyzer with the characteristics of the tape deck included in the tolerance envelope, we get the plot of Figure 2-49, which shows the test spectrum very close to nominal.

Other functions that were run and checked included the hold and stop keys. Both performed as designed and afforded the test operator complete control to halt or terminate the test at any time, and to resume testing from the halt or any time in the program with complete timing documentation. A troubleshooting program is also available which allows the operator to run the system with any single



R81-0639-030W

Fig. 2-48 Microprocessor System Playback of Control Accelerometer from Tape Loop

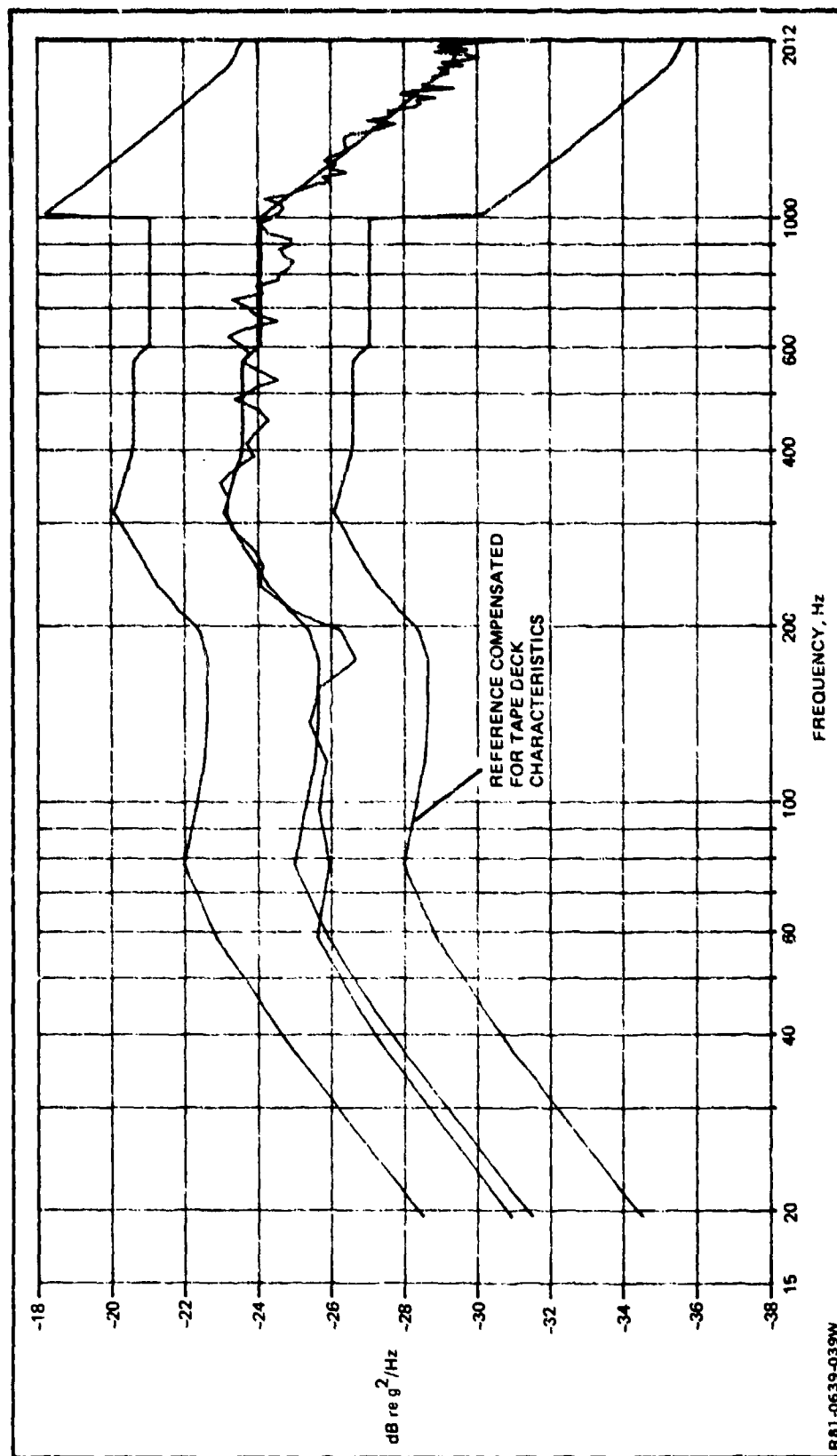


Fig. 2-48 Microprocessor System Compensated Playback of Control Accelerometer from Tape Loop

or combination of environments, at test levels which he specifies while he troubleshoots the electronic system under test. This program was run and its performance verified.

During each test run, spectrum analyses were made of the control accelerometer to verify the test spectrum. All were within tolerance. See Figure 2-50 for a typical plot. In addition, the printer supplied, at 15-second intervals, a printout of required temperatures and acceleration, actual measured values, time in the program, and any tolerance exceedances. See Table 2-19 for a portion of a typical printout.

2.4.6 Conclusion and Recommendations

The system performance in controlling a reliability demonstration test was faultless once initial program bugs were ironed out. Temperature and acceleration levels were maintained within tolerance and time events such as test article power turn-on were handled without problems. Once started, operator attention is required only for periodic checks. Out-of-tolerance alarms and emergency shutdowns all worked automatically without problems, and provide a high degree of test safety.

With regard to the microprocessor system, problems were encountered with the use of A-D and D-A boards added to the system. In particular, the manufacturer's literature specified that the A-D board had built-in cold-junction references for the thermocouple inputs, but the manufacturer's representative could not get the board to work without Grumman-supplied external cold-junction references. As mentioned in previous sections, the use of the manufacturer's solid state relay board and modules would not be recommended because of their limitations in audio and low-voltage applications. The microprocessor itself performed well and the high-level BASIC language is easy to learn and apply in programming the system.

The tape deck also performed flawlessly throughout the program. It should be noted, however, that use of this deck and the "endless-loop" cartridge to supply the random vibration is only one approach for a particular test requirement. The system would work equally well with the reel-to-reel tape deck of

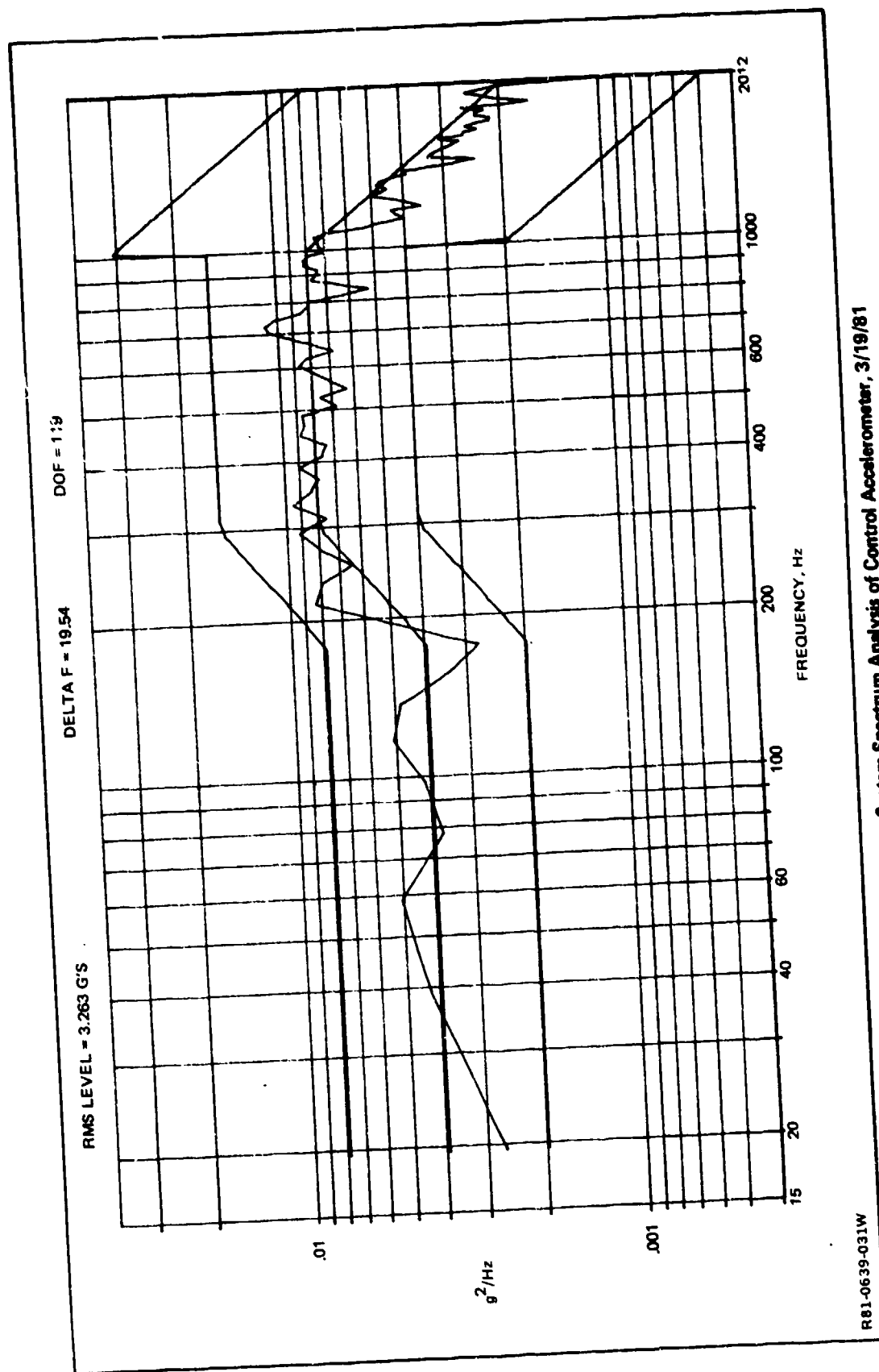


Fig. 2-50 Microprocessor System Spectrum Analysis of Control Accelerometer, 3/19/81

the Multiplex system. Use of multiple spectrums or excitation mediums (such as the cannon firing of the Multiplex demonstration) can also be readily achieved with this system.

In regard to recommendations for future utilization of the system, it should be pointed out that we have used only a small portion of the capability of the microprocessor in this program. The computer has full graphics capability which can be used to plot test data, program profiles and tolerances. It has two floppy discs available for data storage. It has extensive mathematic capability to operate on stored data to compute heating rates, relative humidity, statistical parameters, etc. In short, it is recommended that programming effort be directed to refining the existing program and expanding their application and usefulness to the full capability of the microprocessor.

3 - RECOMMENDATIONS AND CONCLUSIONS

The performance of both the Multiplex and Microprocessor systems was above expectations. To substantiate the reliability of each system, a full eight-hour cycle was completed, with every function performing as anticipated.

In order to accelerate the operation of each of the various start, control and monitor functions, as well as the environmental parameters, several 30-minute Multiplex and 45-minute Microprocessor demonstration tests were performed. The purpose was primarily to establish the integrity of the system and determine its repeatability. The system requirements were met during all of the above operations.

Table 3-1 describes the various features of both the Multiplex and Microprocessor systems. Although more expensive, the Microprocessor system has greater capability than the Multiplex system. A cost analysis was completed to determine if the study goal of developing an inexpensive system or systems to perform Reliability Demonstration testing was reached.

The total cost associated with the Multiplex system is approximately \$3500. This includes the purchase of the reel-to-reel recorder, the components to assemble the display panel, miscellaneous material, and the labor cost to assemble the entire system.

The Microprocessor system cost was approximately \$15,000, considerably more expensive than the Multiplex system. However, it contains essentially unlimited capability that will reduce expensive manpower and equipment failure diagnostic costs. The \$15,000 figure includes the purchase of the microprocessor printer, cassette recorder, tapes, A-D converter, I/O boards, miscellaneous components and the manpower costs to assemble the system.

In comparing the major features of each of the systems, the Taped Random technique to generate the dynamic input requirements is readily adaptable to either the reel-to-reel or tape cassette recorders.

Table 3-1 Comparison of Systems

FEATURE -----	MULTIPLEX -----	MICROPROCESSOR -----
o Length of Mission Cycle	8 Hours Max	Unlimited
o Length of Rel. Demo. Test	Unlimited	Unlimited
o Usable with any Temp. Chamber	No - Programmer Required	Yes
o Usable with any Electro Shaker	Yes	Yes
o Monitors Temperature	No *	Yes - 2 channels
o Controls Temperature	No *	Yes - 2 channels
o Monitors Acceleration	Yes	Yes
o Controls Acceleration	No	No - has capability
o Tolerance Exceedance Alarm	No	Yes
o Temperature Overtest Shutdown	No	Yes
o Acceleration Overtest Shutdown	Yes	Yes
o Records Control Accelerometer	No	Yes
o Records Acceleration Grms	No	Yes
o Records Temperature	No *	Yes - 2 channels
o Records Time Test Log	No	Yes
o Hold Capability	Yes - Not Vib.	Yes
o Positive Synchronization (Temp - Vib - Time)	No	Yes
* - Environmental Test Chamber performs these functions		
R81-0639-057W		

With respect to the control/monitor functions, the Multiplex system has only the capability of controlling the vibration input signal through an acceleration overtest shutdown network designed for safety considerations. None of the other environments or functions are monitored or controlled other than by the activation of a start or stop signal initiated through the Multiplex discriminators. The Microprocessor system not only has the capability to control and monitor each signal, but incorporates a real-time alarm system and printer to document the results during the entire Reliability Demonstration test.

One of the major advantages of the Microprocessor is that, since programs such as CALIBRATE, SETUP, DEMO, TROUBLESHOOT and RELDEM are included in the study, any potential user of this system who can program in BASIC can easily modify the program to reflect his Reliability Demonstration Profile. In order to initiate his test, the only major tasks would be to wire in his chamber to the computer interface hardware associated test instrumentation and generate a vibratory input for the tape recorder from his random source or have it generated utilizing the Taped Random technique.

APPENDIX A

MULTIPLEX SYSTEM PROCEDURE

CONTENTS

<u>Section</u>	<u>Page</u>
A1 INTRODUCTION	A-1
A2 EQUIPMENT REQUIREMENTS	A-3
A2.1 Environmental Test Chamber	A-3
A2.2 Electrodynamic Exciter	A-4
A2.3 Tape Recorder	A-5
A2.4 Multiplex System	A-5
A3 SYSTEM SETUP	A-7
A3.1 System Interfaces	A-7
A3.1.1 Temperature-Humidity Chamber Interfaces	A-7
A3.1.2 Vibration System Interface	A-8
A3.1.3 Test Article Support Equipment Interfaces	A-8
A3.2 Tape Programming	A-8
A3.2.1 Synthetic Random Voltage	A-11
A3.2.2 Multiplex Control Channel	A-18
A4 TEST OPERATIONS	A-23
A4.1 System Calibration	A-23
A4.2 Testing with the System	A-24
A4.2.1 Test Setup	A-24
A4.2.2 Setup Phase of Tape	A-25
A4.2.3 Test Runs with Tape	A-28
A4.2.4 System Holds, Stops and Resets	A-28
A4.3 Test Data	A-30

ILLUSTRATIONS

<u>Figure</u>	<u>Page</u>
A-1 Test Chamber Interface Diagram	A-9
A-2 Multiplex Test System	A-10
A-3 Sine Transfer Characteristics E/G, Measured at Room Temperature	A-13
A-4 Reliability Test Profile	A-15
A-5 Multiplex System: Recorded Random Voltage, Temperature Compensated	A-16
A-6 Multiplex Mainframe Chassis	A-21
A-7 Meter and Control Circuits	A-27

<u>Table</u>	
A-1 Multiplex System - Reliability Demonstration Test Event Schedule	A-17

A1 - INTRODUCTION

The procedure described herein utilized an inexpensive multiplex system to perform a Reliability Demonstration test in accordance with MIL-STD-781C. Since each Reliability Demonstration test profile is different, this procedure assumes that the desired test profile has been developed and the task at hand is its implementation.

This system comprises a multiplex control and programming unit, and a reel-to-reel tape recorder with a pre-programmed tape that defines the desired random test profile, and frequency signals to trigger the desired functions. The functions include the activation of the environmental parameters i.e., temperature, humidity etc., as well as the signals to trigger the test equipment operation.

The reel-to-reel recorder must be capable of continuous operation with the capability of defining a reliability test cycle of eight hours or less. Since each cycle is repeated, the test can be run for as many cycles as required.

For test article protection from overtest, the Multiplex System incorporates an acceleration meter and relay to shut down the electrodynamic exciter automatically if the pre-programmed level is exceeded. In addition, an alarm system providing visual and audible warning is included.

This procedure details the equipment requirements, system setup and the test operations to perform a reliability demonstration test program.

A2 - EQUIPMENT REQUIREMENTS

The equipment required to apply the Multiplex technique to long-term reliability demonstration test can be divided into two categories:

- (1) Normal Environmental Laboratory Equipment
- (2) Special Multiplex Equipment.

Included in the first group would be the:

- Temperature-Humidity Chamber with its associated instrumentation and controller
- Electrodynamic Shaker System, with a sinusoidal control system and associated instrumentation.

The above equipment is available in most small laboratories.

The second group of equipment would consist of:

- Taped-Random equipment, including the tape deck and True - RMS meter.
- Multiplex chassis and tape programmer.

This specialized equipment will have to be purchased and assembled by the laboratory to perform the Reliability Demonstration test.

This section will outline the specific attributes that the test equipment must have in order to operate successfully with the Multiplex System. The intent was to include the more widely used type of equipment found in today's test lab. Less common equipment not specifically described could probably be adapted to this method using the type of approach applied herein.

A2.1 ENVIRONMENT TEST CHAMBER

The required characteristics of the test chamber are determined by the test profile specified for the equipment to be tested. The chamber must be

capable of operation over the required temperature and humidity range within the specified test tolerance and with the required transition rates demanded by the profile. The chamber must have an independent temperature/humidity programmer and controller with a recyclable programmer of sufficient duration to encompass the profile.

The most common type of programmed controller that satisfies this requirement would be a cam type. In the normal installation, two cams would be used, one for dry bulb and one for wet bulb temperature. This type of programmer is ideally suited for use with the Multiplex system. Two areas of caution should be mentioned with regard to use of the cam programmer, however.

The first concerns the length of the profile cycle. The available gear ratios used with the cam drive limit the cam cycle usually to even increments of hours, such as 4, 6, 8, 12, 24 and 48. The profile cycle must be compatible with the available cam cycles. The second area of concern is also associated with timing, i.e., because of play in the gears, it is difficult to set the starting point of the cam with exact precision. Therefore, timing errors between the cam and the tape of 15 to 30 seconds per hour are not uncommon. These errors will accumulate for at least the duration of the first cycle. Therefore periodic checks on the synchronization of the cam and the tape program are frequently required, and the cam position adjusted manually when necessary.

For humidity testing, the chamber should have solenoid valves for filling and draining of the water system. This is required when the mission profile requires temperatures below freezing. These valves can be readily installed in a chamber's water system and an on-off switch for water added to the chambers.

The only other requirement for the chamber is an access entry for the exciter. A flexible air-tight seal between the exciter head and the chamber should be installed to minimize heat loss from the chamber.

A2.2 ELECTRODYNAMIC EXCITER

An electrodynamic exciter system is required with sufficient force capability to drive the test package to the required test level. Sufficient instrumentation and control equipment to perform servo-controlled sinusoidal frequency

sweeps is required. The only additional equipment which might be required is a true RMS meter for accurately measuring the random vibration.

It should, however, be noted that the "G-RMS" meter built into the Multiplex system requires a DC signal (proportional to acceleration amplitude) from the accelerometer charge amplifier. If a charge amplifier with a DC output is not available, an AC meter could be substituted in the Multiplex system.

One additional item of equipment might be required for older exciter systems. Many of the older systems require a high-level input signal to the power amplifier (up to 10 VAC). Since normal stereo tape decks only provide about 1 VAC, a preamplifier would be required between the tape deck and the power amplifier. The preamplifier used should have a 20 dB gain with a frequency response of ± 1 dB from 20 to 2000 Hz.

A2.3 TAPE RECORDER

The tape recorder selected to support the Multiplex System could not be a standard cassette recorder because of the long-term playback requirement. The use of shutdown and rewinding periods throughout the testing would not be desirable. Also, since both channels would very likely be recorded independently, sound-on-sound recording would be a requirement. Finally, the frequency response characteristics should be ± 3 dB from 20 to 2000 Hz for the recording of the random vibration spectra in accordance with NAVMAT P-9492. The reel-to-reel recorder selected should meet these requirements. The use of sensing tape, and/or counter actuation of the "Auto Repeat" and "Auto Reverse" should permit the recorder to play back in both directions for an indefinite period. It also should be capable of recording each channel independently, permitting recording of the vibration spectra and control signals to be at different times.

A2.4 MULTIPLEX SYSTEM

The Multiplex System uses prerecorded stereo tapes containing the vibration spectrum and control signals, each on different channels. During playback of the tape, the control signals are used to provide "on/off" control of a total of eight test environments or instruments. These signals have to be recorded to coincide with the particular mission profile (time versus environment).

The system is composed of three interconnected components. (1) A reel-to-reel stereo tape recorder to be used to both record and play back the mission control profile. (2) A tape programmer to provide capability to record the various frequencies used as control signals (an audio oscillator repeatedly tuned and adjusted for level would also be adequate). (3) A Multiplex Mainframe to extract the control signals from the tape and converts these signals to an "on/off" switch function. The equipment to be controlled is then wired or adjusted so that only "on/off" control is needed. The final step prior to testing is the connection of the test equipment to the appropriate terminals on the barrier strip on the rear of the Multiplex Mainframe.

A3 - SYSTEM SETUP

The setup of the system prior to test operations can be divided into two sections:

- (1) Interfacing the Multiplex System with the environmental test equipment.
- (2) Programming the Multiplex tape for the required test profile.

A3.1 SYSTEM INTERFACES

The Multiplex System interfaces electrically with three test items:

- (1) Temperature - humidity chamber
- (2) Vibration system
- (3) Test article support equipment.

A3.1.1 Temperature-Humidity Chamber Interfaces

The Multiplex System is designed to utilize the chamber internal program controller for maintaining the test temperature-humidity profile. Therefore, only three chamber functions are controlled by the Multiplex program:

- (1) Temperature Air Circulator - which turns on the chamber heat exchange blower and serves as a master switch for all heaters and coolers.
- (2) Program Start - which turns on the cam drive motor or other programmer devices used to control the temperature-time profiles.
- (3) Water Supply - fills or drains the chamber humidity water system

The Multiplex control relays are wired in parallel with each of the chamber switches controlling these functions. During a Multiplex-controlled test these switches are left open on the chamber, thus shifting control to the Multiplex relays. With the Multiplex System disconnected or relays open, the switches will

function normally for manual operation of the chamber. See Fig A-1 for a diagram of a typical chamber interface.

A3.1.2 Vibration System Interface

The input for the vibration system is provided by the left channel of the Multiplex tape deck. This signal is wired through the Multiplex control relay and directly to the audio input of the shaker power amplifier. As noted previously, older exciter systems may require a preamplifier between the tape deck and the power amplifier.

The control accelerometer is mounted on the test fixture and connected through a charge amplifier to a true-RMS meter. The DC output of the charge amplifier is connected to the "G - RMS" meter and relay in the Multiplex System. This meter/relay functions as vibration overtest protection for the test article. It must be wired into the exciter safety shutdown system.

Most exciters are equipped with two internal safety switches: an over-travel switch and an over-temperature switch. Both of these switches are normally closed. When open, they drop out a system relay in the power amplifier, which must be manually reset before testing can be resumed. The multiplex meter-relay must be wired in series (normally-closed contacts) with either of these shaker safety circuits. A normally-open bypass switch should be provided to cutout the Multiplex System when it is not being used.

See Fig. A-2 for a diagram of a typical system interface.

A3.1.3 Test Article Support Equipment Interfaces

Provision for up to five controlled interfaces, with the test article support equipment; is provided in the Multiplex system. Each is a 15-Amp switch circuit. The circuits can be wired in parallel with support equipment switches to turn power on to the test article, turn on cooling air when required, and initiate test functions such as high and low input voltage.

A3.2 TAPE PROGRAMMING

The tape recorder channels are programmed with a random vibration spectra on the left channel while control signals are recorded on the right channel. The two channels may be programmed either simultaneously or separately, since

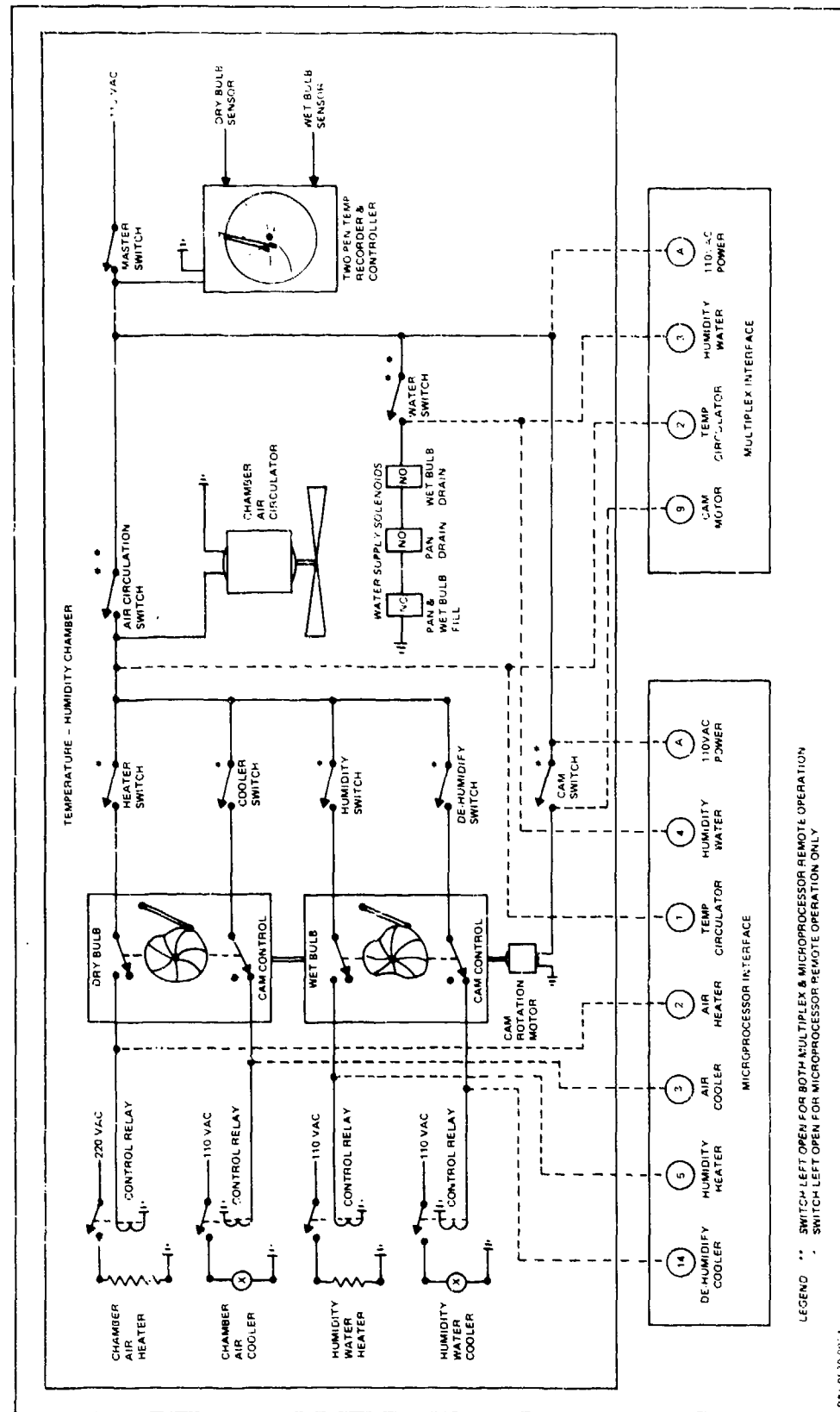


Fig. A-1 Test Chamber Interface Diagram

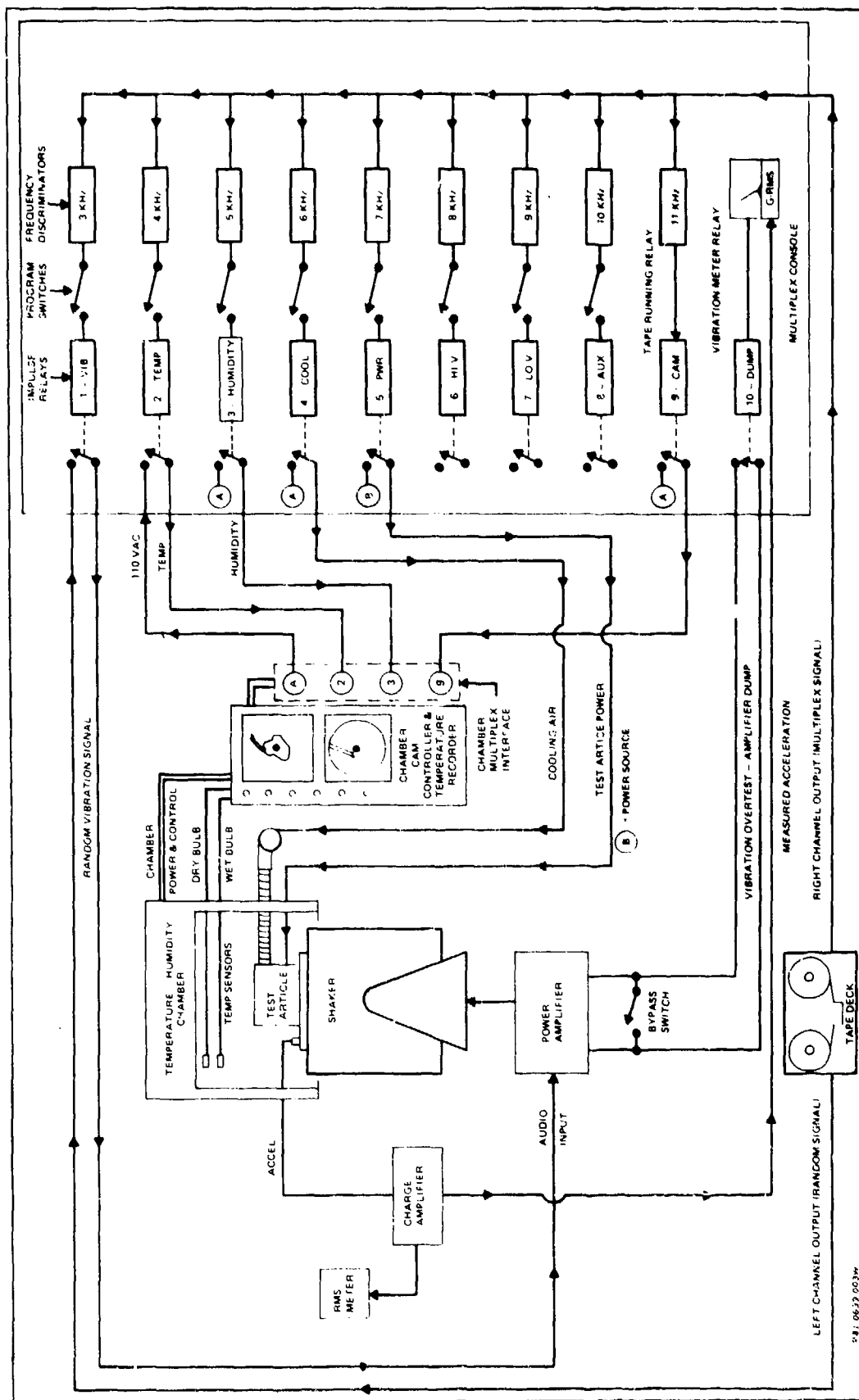


Fig. A-2 Multiplex Test System

the recorder has sound-on-sound capability, whichever is convenient. The left channel is programmed in accordance with NAVMAT P-9492 but, since the Multiplex System only provides "on/off" control, a modification to the procedure is required. The modification consists of recording the same spectrum at various dB levels, each level to be placed on the tape corresponding to its time sequence on the test profile. Thereafter, when the vibration control is turned "on", the spectrum and level are automatically available to the power amplifier and so no adjustments are necessary. The right channel is recorded with a constant 11-kHz signal and various control signals from 3 kHz to 10kHz. The 11-kHz signal represents the "tape running" signal, which is routed to the test clock and temp/humidity cam control circuit. The remaining control signals provide control over the external equipment connected to the multiplex mainframe output barrier strip.

A3.2.1 Synthetic Random Voltage - The tape-random technique is completely described in the referenced document, NAVMAT P-9492. Therefore, in this section we will outline modifications to the procedure which are necessitated by the unique requirements of the Multiplex System and the test profile. The significant differences between the screening test of NAVMAT P-9492 and the Reliability Demonstration test of MIL-STD-781C can be summarized as follows:

- (1) Single test article and setup used for entire test program
- (2) Several different levels of vibration used.
- (3) Test article vibrated over a wide temperature range.

A3.2.1.1 Sine Transfer Characteristics - The sine transfer characteristics are recorded in the same way as described in NAVMAT-P-9492. However, because of the wide temperature range of the test, it is recommended that the sine transfer characteristics be recorded at the two temperature extremes in addition to the normal room temperature sweep. [With some types of mounting systems, thermal expansion can cause significant shifts in the major resonant frequencies.]

It is also recommended that, because of the requirement for different test levels, a linearity check be made by recording sine sweeps at both 1.0-g and 3.0-g, from 20 to 2000 Hz.

The sine tape will have the following sine sweep recorded on it:

- (1) 1.0 g - room temperature
- (2) 3.0 g - room temperature
- (3) 1.0 g - lowest temperature
- (4) 1.0 g - highest temperature

This will require approximately 40 minutes of tape. A typical sine transfer curve is shown in Fig. A-3.

A3.2.1.2 Preparation of Synthetic Random Tape - The analytical calculations of the synthetic random voltage is performed in essentially the same manner as described in NAVMAT P-9492. Each of the four sine sweeps is played through a real-time analyzer and the sine transfer function determined (E/g). If there are minor differences in the function at low and high temperature, the two functions should be averaged. Compensation factors for linearity (based on the two room-temperature runs) can be applied to this averaged function. Since the same test article is used throughout the test program, no compensation factors for variance are used.

If, however, the differences in the transfer function due to temperature or linearity are large enough to cause out-of-tolerance amplitudes at any temperature or test level, two separate synthetic random spectra can be calculated and recorded at the appropriate time on the tape.

A3.2.1.3 Recording the Random Tape - The synthetic random noise is recorded in essentially the same manner as outlined in NAVMAT P-9492, with the following exceptions.

Since verification of the test setup using the recorded sine sweep is only required once at the start of the test program, the sine sweep tape is kept separate from the random tape. If the test lab has a spectrum analyzer, verification of the test setup can be made directly with the random tape.

The length of the random tape is determined by half of the required program cycle (since tape is run in both directions) plus a five-minute setup time used to set the amplifier gain at the start of the test. Using the program profile (see typical profile Fig. A-4), a schedule is written for the required changes

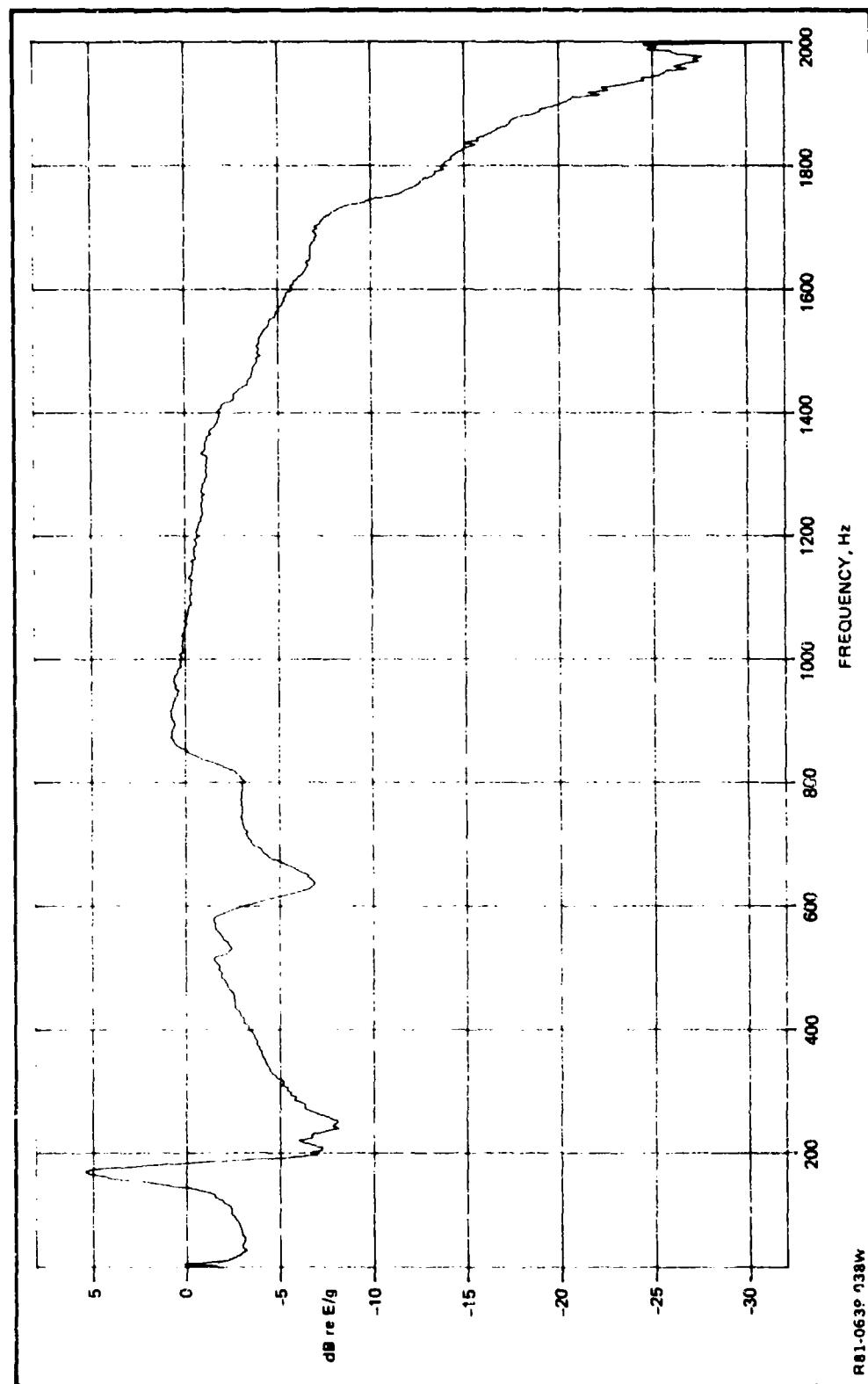


Fig. A-3 Sine Transfer Characteristics E/G, Measured at Room Temperature

in test level. The random equalization system is then programmed with the calculated synthetic voltage. This voltage is assigned a 0 dB value. An attenuator is used to reduce this voltage to that required by the profile (see typical random voltage curve, Fig. A-5).

To record the tape, the random equalization system is run in a closed-loop mode (the output is fed into the control accelerometer loop) with the output paralleled to the input of the left channel. Before the tape drive is started, the recording level of the tape deck is adjusted to 0 dB with the random equalization system set for 0 dB output.

The recording is started by activating the tape deck drive with the system in the RECORD mode. Test levels are switched manually (using the attenuator) at the required times in the test profile. [This can also be programmed in digital random vibration consoles.] At the conclusion of the initial five minutes of tape [used for system setup] the tape deck should be stopped and the tape counter set to zero. A piece of visual cueing tape should be bonded to the tape to locate the program start point. The tape deck can then be restarted and the program recorded. During recording, the counter reading at test events should be recorded on the test profile table (Table A-1).

At the completion of the first half of the test program, the tape drive is stopped and a 3/8" length of aluminum foil tape bonded to the recording side of the tape. [This is used to switch the tape into reverse side play.] Side two of the tape is then recorded in exactly the same manner as side one, but without the five-minute setup portion. In order to record side two, many tape decks require that the reels be interchanged [these decks have four playback heads but only two record heads]. If this is required, the reels should be again interchanged at the conclusion of the recording.

When separate random voltages are required at different times in the test profile, a similar procedure is followed except the tape drive must be stopped while a different random equalization is shaped by the vibration control system. The recording levels must also be normalized so that the initial gain setting provides the required test level for each spectrum. [This normalization voltage can be determined experimentally prior to recording the tape.]

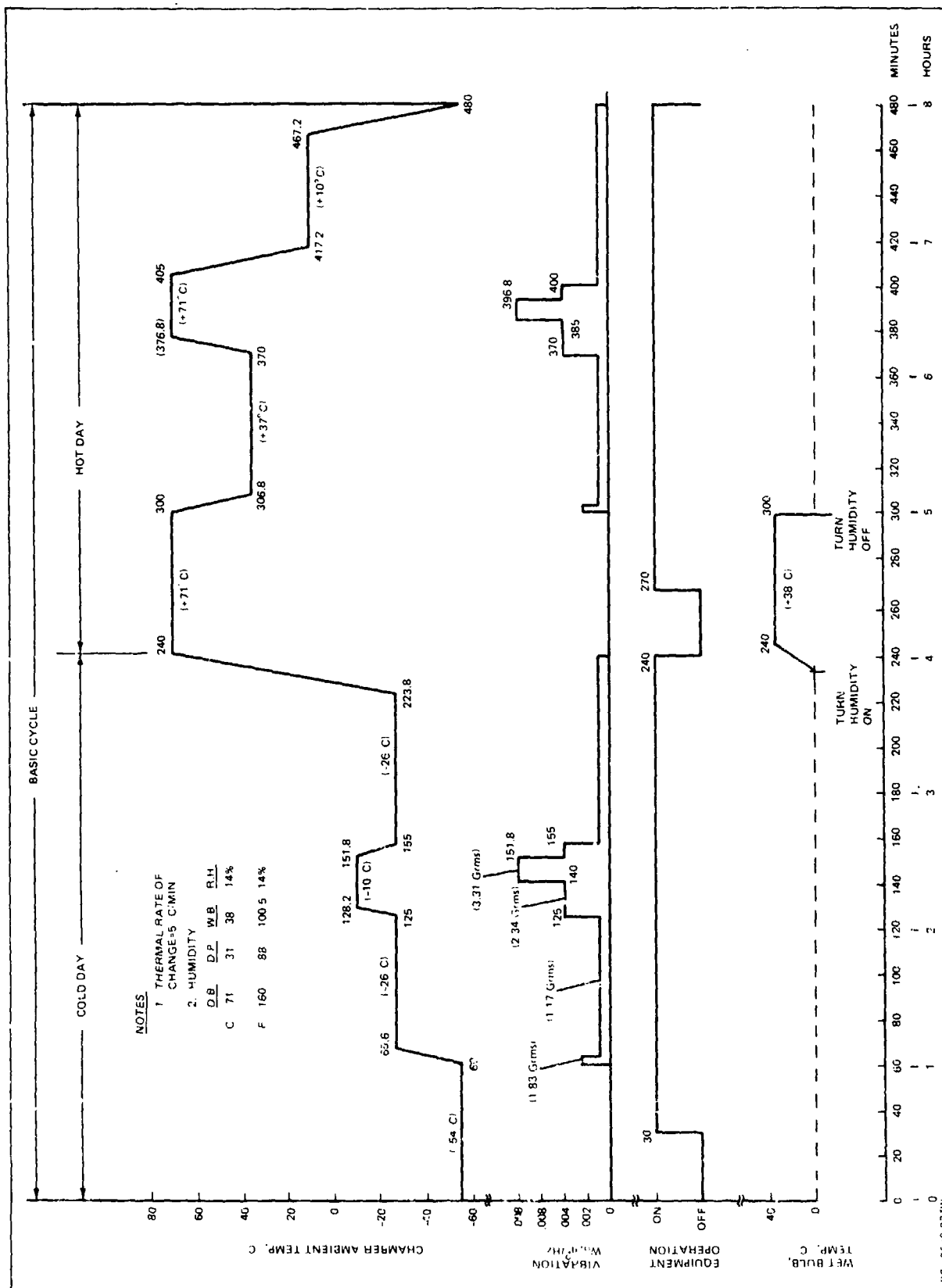


Fig. A-4 Reliability Test Profile

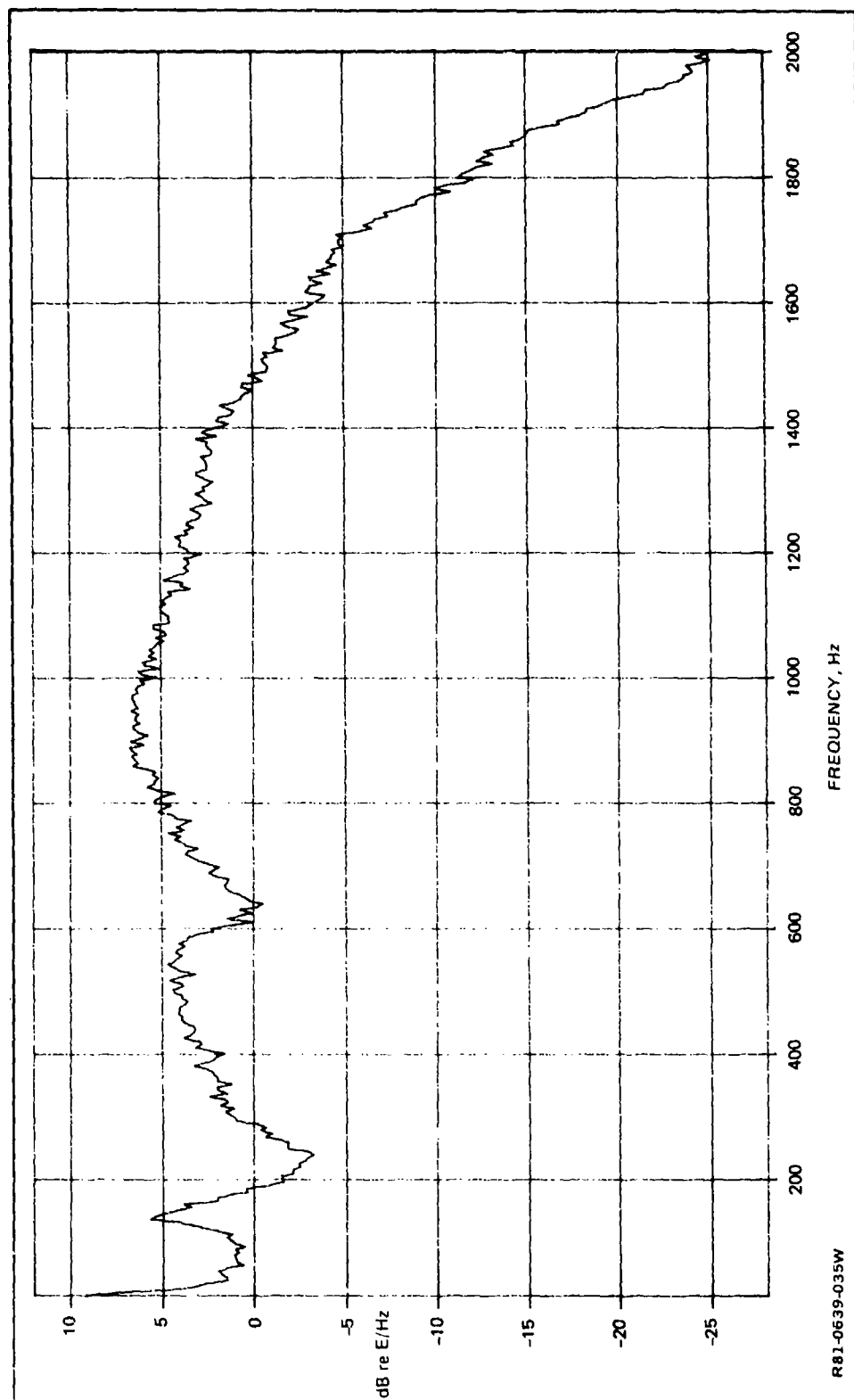


Fig. A-5 Multiplex System: Recorded Random Voltage, Temperature Compensated

Table A-1 Multiplex System — Reliability Demonstration Test Event Schedule

PROGRAM TIME HR	TAPE COUNTER	VIB	TEMP	HUM	PWR	COOL	VIB LEVEL	REMARKS
-0.08	9700	ON	OFF	OFF	OFF	OFF	0 DB	SETUP PHASE
-0.02	9920	OFF	"	"	"	"	0 DB	"
0.00	0000	"	ON	"	"	"	-	START
0.50	0470	"	"	"	ON	"	-	
0.75	0724	ON	"	"	"	"	-	
1.00	0960	"	"	"	"	"	-5 DB	
1.03	0991	"	"	"	"	"	-9 DB	
2.08	2129	"	"	"	"	"	-3 DB	
2.33	2426	"	"	"	"	"	0 DB	
2.53	2672	"	"	"	"	"	-3 DB	
2.58	2735	"	"	"	"	"	-9 DB	
3.83	4548	"	"	ON	"	"	-9 DB	
4.00	4849	OFF	"	"	OFF	"	-	
4.00 *	4852	"	"	"	"	"	-	* TAPE REVERSES
4.50	4013	"	"	"	ON	ON	-	
4.75	3641	ON	"	"	"	"	-	
5.00	3287	"	"	OFF	"	"	-5 DB	
5.03	3250	"	"	"	"	"	-9 DB	
6.17	1850	"	"	"	"	"	-3 DB	
6.41	1580	"	"	"	"	"	0 DB	
6.53	1450	"	"	"	"	"	-3 DB	
6.58	1400	"	"	"	"	"	-9 DB	
7.98	0004	OFF	OFF	"	OFF	OFF	-	
8.00 *	0000	"	"	"	"	"	-	* TAPE REVERSES

A3.2.2 Multiplex Control Channel

A3.2.2.1 Test Profile - Prior to recording of any of the control signals, a tabulation of test equipment condition (on/off) versus test time must be available. The time increments of the tabulation should be in hours. The least increment possible is 0.01 hours (36 seconds), in order to coincide with the mainframe test clock. This tabulation, or schedule, will be used to determine when a control signal is to be recorded on the tape.

A3.2.2.2 Tape Programmer Setup - Power to the programmer is furnished by the Multiplex Mainframe, and therefore the mainframe must be powered during the setup. Overall power to the programmer is then controlled by its own power switch. The programmer consists of nine function generators, each with its own front panel switch, eight red-handled and one white. Placing the switches to the up position powers that particular generator, and its output signal appears at both the front and rear panel connectors simultaneously.

Above each switch is engraved the nominal output frequency of the generator controlled by the switch. While the output is monitored, at the front panel with an electronic counter, the frequency of each generator should be adjusted to $\pm 5\%$ of the nominal. Adjustments are made by using the appropriate potentiometer mounted behind the upper right hand corner of the front panel. Access holes for each potentiometer are provided on the front panel. Each generator should be adjusted independently. The output amplitude of the generators have been previously adjusted directly on the circuit board installed on the programmer chassis. No further adjustment should be necessary to the output amplitudes.

The output jack mounted on the rear panel of the programmer chassis should be connected to the right channel line input of the recorder. Either programmer output jack may be used, since they are internally connected. A standard audio cable may be used for the interconnection, these cables are normally furnished with the recorder.

A3.2.2.3 Tape Preparation - A test tape will contain two test segments, one to be played back in the forward direction while the other is played back in the reverse direction. The length of time of each test segment will determine the tape

selection. A test segment in excess of four hours, or total cycle time of eight hours, requires a thin (1.0 mil) tape. The 1.0 mil tape test cycle is then limited to the amount of tape placed on a ten-inch reel. A minimum of 4500 feet of 1.0 mil tape is required for an eight-hour test cycle. Generally, 1.0 mil tapes are supplied on 2700 ft. seven-inch reels. Therefore, a splice will be required as well as a transfer to the 10-inch reel. The use of a tape splicer is recommended for both its quality of workmanship and its convenience. (Note: Whenever possible, the 1.0-mil tape should be avoided in order to lessen the possibility of tape stretch and breakage.)

A3.2.2.4 Recorder Setup - (Note: Before attempting to use the reel-to-reel recorder, a familiarization with its controls and performance is recommended. This may be accomplished by means of the Operator's Manual and practice recordings.) The recorder input power connector should be plugged into the auxiliary power connector located on the rear panel of the Multiplex Mainframe, Fig. A-6. Thereafter, the recorder power is controlled through the Mainframe and the recorder power switch may be left in the "on" position.

The recorder controls should be placed in the following positions:

- a) Tape Speed: 9.5 cm/sec (3.75 in/sec)
- b) Record left channel: 'OFF'; right channel: 'ON'
- c) Monitor/Source Selector: Source
- d) Bias & Equalization: Both on '1'
- e) Reel Size: Large (assuming eight hr test cycle)
- f) Pitch Control: Remains at center point throughout record
- g) Timer & Repeat: Both 'off'
- h) Counter: Reset to 0000
- j) Pause, Record & Forward: Activated per Operating Manual

A3.2.2.5 Recording Control Signals - This section presumes that the Random Vibration Spectrum has been recorded in accordance with Para. 3.2.14 prior to recording the control signals. Therefore, discussion concerning the first five-minute setup and placement of the cueing mark and tape reversal indicator is not necessary.

The entire Multiplex system should be powered and permitted to warm up for several minutes. During the warm-up period, pre-recording checkout of the programmer and recorder should be performed in accordance with Paras. 3.2.2.2 and 3.2.2.4. After the checkout is completed, the tape should be advanced to the cueing mark that indicates the end of the five-minute set-up and start of the test cycle. A review of the environmental/test equipment "on/off" profile should be made just prior to recording. Also, since the tape recorder will only record in the forward direction, when the first test segment is completed the recorder reels must switch location in order to record the reverse direction signals.

Prior to recording, turn on the tape running generator, 11 kHz (white handled switch) on the programmer and adjust the Right Channel Record level for 0 dB on the recorder meter. Press the "Pause" button. This should activate the Record/Forward motion of the tape. Avoid stopping the tape until the tape reversal indicator is reached. Stopping the tape places interruptions in the Tape Running Signal which controls the cam motor. As the time for each "on" or "off" condition is reached, (Para. 3.2.2.1) the appropriate generator switch should be placed on momentarily for two to three counts of the tape counter. With the tape running signal indicating 0 dB on the tape meter, the momentary pulses from the other generator will be visible on the tape meter by causing the level to reach approx. +3 dB. It should be remembered that a pulse of control signal is required to shut off an environment as well as turning it on. Therefore, the test profile must contain the shut-down times for each environment.

After the first half of the mission cycle is recorded on the forward portion of the tape, and when the tape reversal indicator is reached, the tape running signal may be shut off. The reels should then be reversed and the recorder rethreaded for recording in the forward direction. Reset the PAUSE, RECORD, and FORWARD switches, place the tape running generator 'on'. Proceed as earlier described for the first forward recording. Upon reaching the cueing mark on the tape, the entire systems may be shut down.

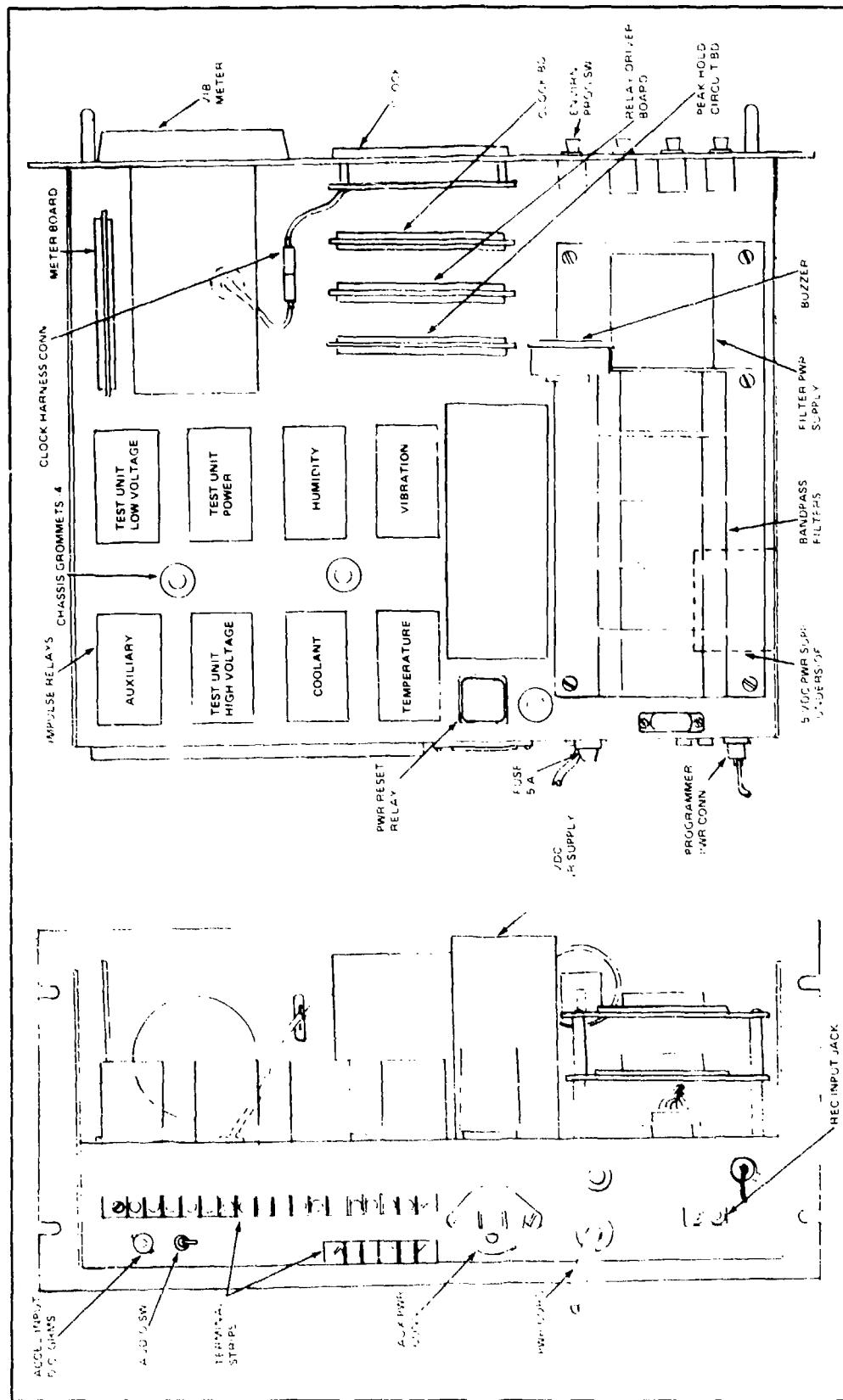


Fig. A-6 Multiplex Mainframe Chassis

A4 - TEST OPERATIONS

The performance of Reliability Demonstration tests with the Multiplex System can be divided into three sections:

- (1) System calibration
- (2) Testing with the system
- (3) Test data

A4.1 SYSTEM CALIBRATION

Other than the normal calibration requirements for vibration and temperature sensing equipment, the Multiplex system has two unique requirements which should be accomplished in the pre-test phase of the program.

The first requirement is for time synchronization between the multiplex program tape and the chamber programmer. As explained previously, there is no positive time synchronization between the chamber programmer and tape except simultaneous starting and stopping. The synchronization, therefore, depends on the cycle time of the chamber programmer and the tape being exactly equal. Since the more common types of chamber programmers, such as a cam, do not have provisions for adjusting the cycle time, it is suggested that the chamber programmer cycle time be used as the reference and the tape cycle time be adjusted to match it.

The cycle time of the tape is controlled by the zero setting of the counter and the position of the aluminum reversing tape. Lengthening of the tape cycle can be readily accomplished by moving the aluminum tape further toward the end of the tape. Since the tape runs in both directions, this doubles the increment. [For example, the cycle can be extended 60 seconds by moving the aluminum tape outboard by 30 seconds or 112 inches.] An 11kHz "tape-running" signal must be recorded throughout the extended portion.

Shortening of the test program can be accomplished in a similar manner or by resetting the tape counter zero for a later start. Note whether any control signal pulses will be lost with the shortening. If they are, a short segment

of the tape will have to be re-recorded and the missing control signal pulses re-recorded.

The second requirement is for a calibration of the "G-RMS" meter in the Multiplex System. This DC meter reads the DC output of the accelerometer charge amplifier, which is proportional to the average of the AC accelerometer output. Since we want the Multiplex "G-RMS" meter to read the true G-rms value of the random vibration, it will have to be calibrated using a true-RMS meter and a random noise source. The easiest way to accomplish this is to operate the shaker using the random tape at 0-dB test level. The attenuator for the Multiplex G rms meter can then be adjusted until it reads the same as the true RMS meter.

A4.2 TESTING WITH THE SYSTEM

Test runs with the system encompassed the initial setup of the test, test operations, and any holds and restarts accomplished.

A4.2.1 Test Setup

The most important aspect of the test setup is assuring that the mechanical and electrical configuration of the exciter system is identical to that utilized in the recording of the sine transfer function. With the setup complete, this should be verified by playing the sine tape back through the exciter system. This verification procedure is explained in detail in NAVMAT P-9492. If a spectrum analyzer is available to the laboratory, verification can be made using the five-minute setup phase of the random tape.

The test chamber must be configured for the start of the test. This should include:

- Cam and chart recorder set to start point
(zero minus five minutes of setup tape time)
- Main power switch ON
- Cam drive, air circulator, and humidify water switch OFF
- Chamber heater, cooler, humidify, and dehumidifier switches ON
- External coolant (LN_2 , CO_2 , etc) valve open if used.

The Multiplex System must be configured for the start of the test. This should include:

- All control relays set to OFF position (red dot on each relay aligned with cam follower)
- Main power switch on
- All required environment program switches ON (temperature, humidity, vibration, equipment power, coolant, etc)
Note: only bottom blue light should come on if relays have been properly set to OFF position
- Test clock switch to START
- "G-RMS" meter relay set to 20% above the highest test level
- Tape deck in playback mode with automatic cycling controls set
- Tape positioned at start of five-minute setup portion of the tape (counter should read the equivalent of minus five minutes from a zero count)

The vibration system must be configured for the start of the test. This should include:

- Exciter in operational mode (field current up)
- Exciter amplitude control OFF
- Bypass switch for exciter shutdown OFF
- Charge amplifier in OPERATE mode
- True RMS meter ON.

This completes the pre-test phase of the test setup.

A4.2.2 Setup Phase of Tape

The initial five minutes of the Multiplex program tape are used for setting up the vibration system for the test. The left channel has the full 0-dB level of vibration recorded on it. The right channel has the vibration-enable signal recorded at the start of the tape. [It is also recommended that the temperature

chamber be turned on at this time to hasten stabilization at the initial temperature/humidity condition].

This full-level vibration signal is utilized for three calibration functions:

- (1) Setting exciter system gain
- (2) Calibrating "G-RMS" meter-relay
- (3) Verifying the test spectrum

The setting of the exciter gain is accomplished with the following steps:

- (1) Start the tape drive
- (2) Verify a vibration signal output by observing the left channel VU meter (should read -10 to 0 dB)
- (3) Turn exciter gain control up until the required 0 dB test level is indicated on the true-RMS meter. [Mark position of the gain control so it can be readily reset after a test halt.]

The Multiplex "G-RMS" meter relay can be set at this time. This is accomplished by adjusting the 200 ohm potentiometer on the meter control board (Fig. A-7) until the meter reads the same as the True RMS meter. This adjustment need not be repeated at the start of each test unless the 0 dB test level is significantly different from that for which it was calibrated.

A spectrum analysis can also be made at this time if a real-time analyzer is available.

The tape may be left running at the conclusion of these calibrations since system control is now being performed by the tape. At the conclusion of the five minutes, the tape counter should read 0000. [It is recommended that a visual piece of cueing tape be put on the program tape at the program start location to facilitate timing]. The counter can be reset to zero if it is slightly off (as indicated by the cueing tape) and the test clock should be started by activating the run switch.

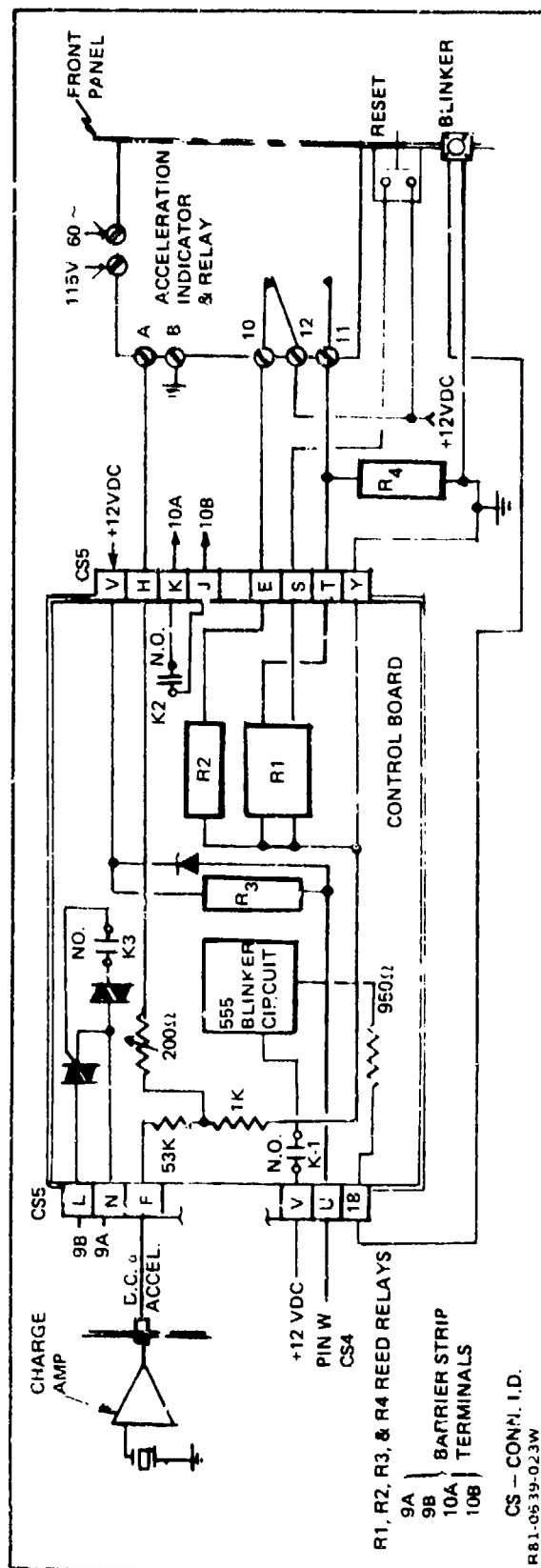


Fig. A-7 Meter and Control Circuits

A4.2.3 Test Runs with the Tape

Once the tape starts into the test program, all operations are automatic:

- Vibration levels are preprogramed on tape
- Temperature-humidity is controlled by the chamber program-controller
- Test article support equipment is also controlled by the tape program.

The only periodic adjustment that may be required is for synchronization of the chamber cam controller and the Multiplex tape. As noted previously, there is no positive synchronization between them and therefore errors of two or three minutes per cycle can be expected. Therefore, it is recommended that, every two or three cycles, the cam be manually readjusted to get it back in sync with the tape program.

During the initial cycle, it is also recommended that timing of events be verified against the program listing to catch any programming errors that may have been made in preparing the tape.

A4.2.4 System Holds, Stops and Resets

Testing can be halted at any time by the following procedure:

- (1) Press the STOP button on the tape deck
- (2) Put the test clock switch in HOLD.

Stopping the tape drive causes the system to go into a semi-hold condition:

- (1) Vibration stops as there is no audio signal to the power amplifier when the tape is not moving
- (2) The chamber program cam halts, leaving the chamber in a "hold" condition - maintaining the temperature and humidity it was set at when the "hold" was initiated.
- (3) The test article support equipment remains in the same condition it was set at when the "hold" was initiated.

In order to change an environmental status during a "hold", two methods can be used:

- (1) The impulse relay switching arm (for the environment or function re-required) can be manually moved into the reverse position.
- (2) The test chamber or test article support equipment switch can be manually reset. (For example, the chamber heating switch could be turned off.)

In order to resume testing from the point of the "hold", the following is required:

- (1) Return any control relay or switches changed during the "hold" to their original position when the "hold" was initiated
- (2) Push tape deck DRIVE switch (make sure drive switch direction is the same as it was at the time of the "hold" initiation)
- (3) Move test clock switch from HOLD to START position.

If testing is to be resumed from some other point in the program than the point at which the program was halted, the following steps are required:

- (1) Manually rotate the chamber program cam to the desired start point.
- (2) Advance or rewind the Multiplex tape to the counter reading corresponding to this program time (see Table A-1)
- (3) Set all the Multiplex control relays to the condition required by the program at this time.
- (4) When the temperature and humidity have stabilized at the new test condition, start the test tape by pushing the tape drive switch in the desired direction.
- (5) Move the test clock switch from HOLD to START position. [Time will continue from time of "hold" condition].

If an overtest vibration shut down occurs, it will activate the electrodynamic exciter system test safety shutoff, but will not interrupt the balance of the Multiplex system program. It will, however, sound an audio alarm to alert the

test operator to the problem. In order to maintain the integrity of the vibration program, the Multiplex System should be halted per the procedure of this section. Press the reset button below the Multiplex meter to turn off the alarm.

Before resuming testing, the operator should determine the cause of any vibration overtest. In particular, he should check the test article or attachment hardware for possible structural failures. When the cause of the problem has been identified and corrected, testing can be resumed as follows:

- (1) Recycle the power amplifier to its operate mode
- (2) Adjust electrodynamic exciter gain control to the mark determined in the system setup. (Para A4.2.2)
- (3) Resume testing using the procedure outlined earlier in this section.

A cautionary note should be made with regard to the tape deck counter. It will reset to zero automatically (without regard to tape position) whenever there is a power interruption to the tape deck. Therefore, it is recommended that the deck not be turned off during the course of a test. If there is a power interruption, the tape counter must be reset by winding the tape to the program start visual cueing tape, and setting the counter to zero. The tape must then be advanced to the desired starting point.

It should also be noted that loss of power to the Multiplex System does not shut off the temperature chamber or test article support equipment. The Multiplex control relays stay in the condition they were at when the test was halted.

For complete shutdown of the system, the Multiplex control relays must be manually set to OFF [red dot on relay switching arm].

A4.3 TEST DATA

The Multiplex System does not monitor or record any test data except total running time. Therefore, it is essential that the test operator maintain an accurate test log in order to document the stress history on the test article. This is of particular importance where the test cycle has been interrupted by holds or shutdowns of the system.

As a minimum, the following information should be recorded for each test cycle:

- (1) Cycle number
- (2) Start and stop time, and date
- (3) Temperature/humidity/vibration time history - continuous if recording equipment available, or periodically if manual data logging must be done
- (4) History of all test halts, including time and conditions during halt, reason for halt, and time in profile where testing was resumed.
- (5) A spectrum analysis should be performed periodically to verify the test spectrum.

APPENDIX B

MICROPROCESSOR SYSTEM PROCEDURE

CONTENTS

<u>Section</u>	<u>Page</u>
B1 INTRODUCTION	B-1
B2 EQUIPMENT REQUIREMENTS	B-3
B2.1 Environmental Test Chamber	B-3
B2.2 Vibration Shaker System	B-4
B2.3 Tape Deck	B-4
B2.4 Microprocessor	B-5
B3 SYSTEM SETUP	P 3
B3.1 System Interfaces	B-9
B3.1.1 Temperature - Humidity Chamber Interfaces	B-9
B3.1.2 Vibration System Interface	B-10
B3.1.3 Test Article Support Equipment Interfaces	B-13
B3.2 System Programming	B-14
B3.2.1 Tape Programming	B-14
B3.3 Microprocessor Programming	B-18
B3.3.1 CALIBRATE Program	B-18
B3.3.2 SETUP Program	B-21
B3.3.3 DEMO Program	B-21
B3.3.4 TROUBLESHOOT Program	B-29
B3.3.5 RELDEM Program	B-31
B4 TEST OPERATIONS	B-33
B4.1 System Calibration	B-33
B4.1.1 Vibration System Calibration	B-33
B4.1.2 Temperature Sensor Calibration	B-34
B4.2 Testing with the System	B-34
B4.2.1 Test Setup	B-34

CONTENTS (contd)

<u>Section</u>	<u>Page</u>
B4.2.2 Test Runs with the System	B-37
B4.2.3 Test Holds, Halts and Troubleshooting	B-39
B4.2.4 Test Data	B-40

ILLUSTRATIONS

<u>Figure</u>		<u>Page</u>
B-1	Reliability Test Profile	B-7
B-2	Test Chamber Interface Diagram	B-11
B-3	Microprocessor Test System	B-15
B-4	Sine Transfer Characteristics E/g	B-17
B-5	Microprocessor System Recorded Random Voltage	B-19
B-6	CALIBRATE Flowchart	B-20
B-7	SETUP Flowchart	B-22
B-8	DEMO Flowchart: Stabilization	B-23
B-9	DEMO Flowchart: Monitor and Control	B-25
B-10	DEMO Flowchart: Hold	B-27
B-11	TROUBLESHOOT Flowchart	B-30

Table

B-1	Microprocessor Control System Printout	B-38
-----	--	------

B1 - INTRODUCTION

The procedure described here utilizes an inexpensive Microprocessor System to perform a Reliability Demonstration Test in accordance with MIL-STD-781C. Since each Reliability Demonstration test profile is different, this procedure assumes that the desired test profile has been developed and the task at hand is the implementation.

The system is composed of a microprocessor with a CRT display, a continuous-loop, cassette tape recorder, and an on-line printer to document timing and relevant test data for each environmental test event. The desired reliability demonstration test profile, as well as the environmental tolerances, are programmed in the microprocessor. During the test (typically, every 15 seconds) the environmental parameters with their associated levels are compared with the required test levels. An out-of-tolerance condition is signaled by a notation on the printer and an alarm bell.

In addition, the procedure contains several programs which enable the user to perform all the necessary reliability demonstration test functions, as well as any diagnostics. The programs are called CALIBRATE, SETUP, DEMO, TROUBLESHOOT and RELDEM, and can be modified by the user to reflect his desired test requirements.

The procedure details the equipment requirements, system setup, and the test operations to perform a Reliability Demonstration Test program.

B 2 - EQUIPMENT REQUIREMENTS

The equipment required to apply the microprocessor technique for long-duration Reliability Demonstration tests can be subdivided into two categories:

- (1) Normal environmental laboratory equipment
- (2) Special Microprocessor equipment

Included in the first group would be the following:

- Temperature - humidity chamber
- Electrodynamic exciter system with a sinusoidal control system and associated instrumentation

This is equipment most small test laboratories would already be equipped with.

The second group of equipment would consist of:

- Taped-random equipment, including the tape deck and true RMS meter
- Microprocessor, peripheral and I/O boards.

This specialized equipment would have to be purchased and interfaced with the laboratory equipment to perform Reliability Demonstration tests.

This section will outline the specific attributes that the test equipment must have in order to operate successfully in the Microprocessor System. The intent was to include the more widely used types of equipment found in today's test labs. Less common equipment not specifically described could probably be adapted to this technique using the same approach.

B2.1 ENVIRONMENTAL TEST CHAMBER

The required characteristics of the test chamber are determined by the test profile specified for the equipment to be tested. The chamber must be capable of operation over the required temperature and humidity range, within the specified tolerance and with the required transition rates demanded by the

test profile. The chamber need not have a temperature controller, programmer, or monitor, as these functions are performed by the Microprocessor System. Chamber functions must, however, be electrically switchable to be interfaced with the Microprocessor.

For humidity testing, the chamber should have solenoid valves for filling and draining of the water system. This is required when the mission profile requires temperatures below freezing. These valves can be readily installed in a chamber water system and an on-off switch added to the chamber.

The only other requirement for the chamber is an entry for the exciter. A flexible air-tight seal between the exciter head and the chamber should be installed to minimize heat loss from the chamber.

B2.2 VIBRATION EXCITER SYSTEM

An electrodynamic exciter system is required with sufficient capability to drive the test package to the required test level. Sufficient instrumentation and control equipment to perform servo-controlled sinusoidal frequency sweeps is required. The only additional equipment required is a true RMS meter for accurately measuring the random vibration.

It should, however, be noted that the A-D module in the Microprocessor requires a DC signal (proportional to acceleration amplitude) from the charge amplitude. [This is to avoid a complicated sampling subroutine on the AC signal to determine the true rms]. If a charge amplifier with a DC output is not available, then a true RMS meter with a DC output should be secured.

One additional item of equipment might be required for older exciter systems. Many of the older systems require a high level input signal to the power amplifier (up to 10 VAC). Since the normal stereo tape deck only provides about 1 VAC, a preamplifier would be required between the tape deck and the power amplifier. The preamplifier used should have a 20 dB gain, with a frequency response of ± 1 dB from 20 to 2000 Hz.

B2.3 TAPE DECK

The recorder used with the Microprocessor system must be capable of meeting the frequency requirements specified in NAVMAT P-9492. These re-

quirements deal primarily with the low-frequency response from 20 to 2000 Hz. The ability to record during simultaneous playback is also a requirement. The Microprocessor system lessens the need for constant surveillance of the test conditions. The capability to record the vibration level just prior to a shut-down or failure becomes a necessity. The use of a cassette recorder with an endless tape is desirable rather than a reel-to-reel recorder since it eliminates interruptions during playback and recording.

B2.4 MICROPROCESSOR

A microprocessor selected to monitor and control test environments to MIL-STD-781C must be capable of performing a number of critical functions. As a minimum, the system must accept inputs from two thermocouples and one accelerometer. These three transducers will provide readings of dry bulb temperature, wet bulb temperature and rms acceleration.

Interface cards and relays required to activate switches are necessary to turn on various controls of the test facility. Since the decision to activate a switch will be based on the three transducer inputs or the time of the test cycle, the Microprocessor must have a clock or programmable timer.

Storage and display of programs and test data is a basic necessity of any system controller. Several methods can be used to provide permanent storage of computer programs. These are the tape cassette, Programmable Read-Only Memory (PROM), and mini-floppy disk. The system selected had dual mini-floppy disks for storage of programs that are required to prepare the environmental facility for testing, run the test profiles and debug test problems that occur. Display of the programs and test results is provided by a CRT terminal with permanent copies of the output on a line printer.

Prior to program execution, the program must be transferred from peripheral storage to the main microprocessor memory. The system evaluated contained 48K of RAM memory, a sufficient amount of memory to perform all the necessary program tasks for the eight-hour test profile (see Fig. B-1).

In addition to hardware requirements, system software is required to perform program functions. A software operating system is necessary to transfer

programs to and from disk storage to the microprocessor memory. To utilize a higher level programming language such as BASIC, and to execute the programs, requires an interpreter/compiler and a software runtime package. The programming and execution become greatly simplified if the language allows real-time event monitoring through interrupts and addressing of specific memory locations for monitor/control.

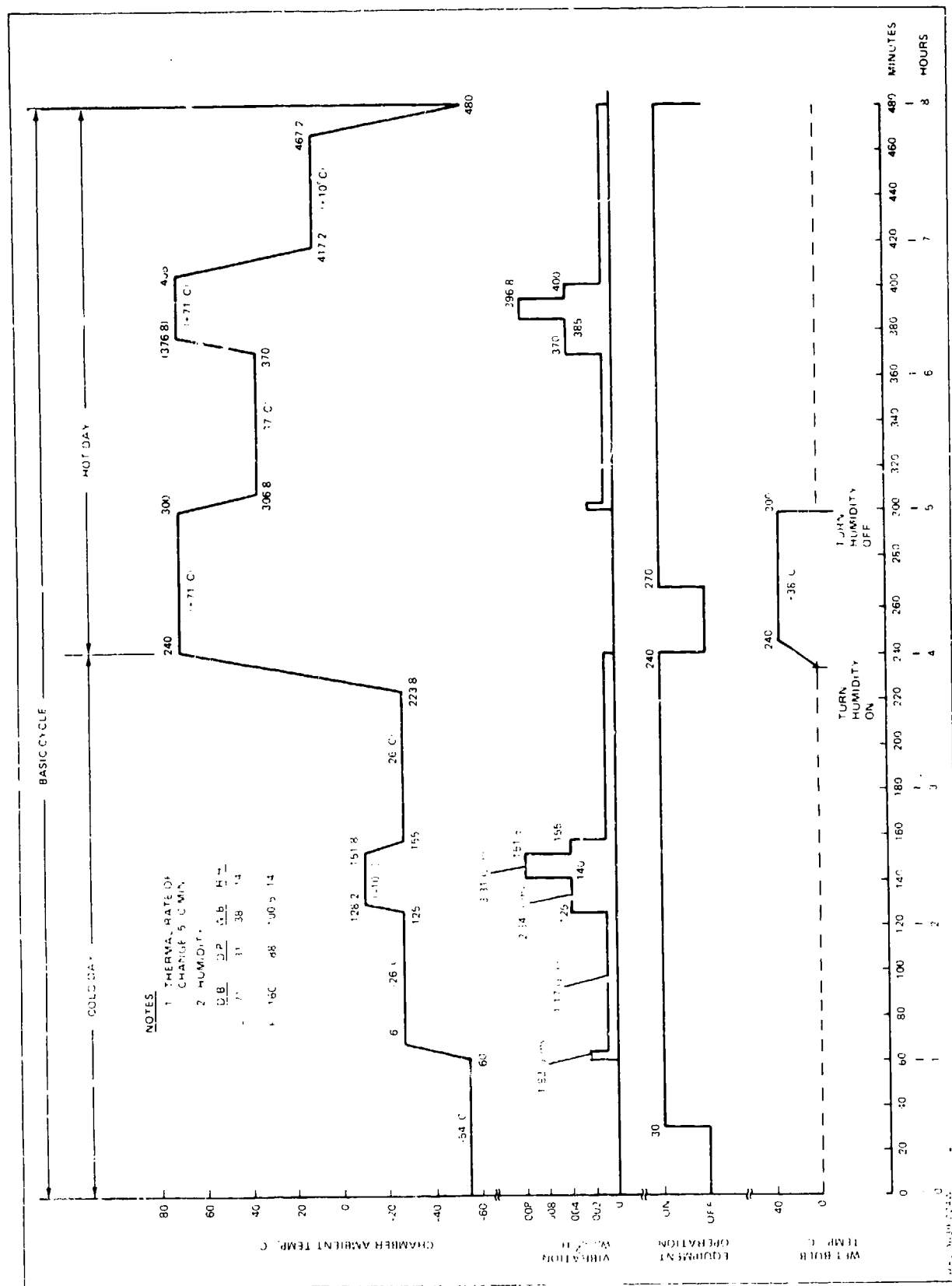


Fig. B-1 Reliability Test Profile

B3 - SYSTEM SETUP

The setup of the system prior to test operations can be divided into two sections:

- (1) Interfacing the microprocessor system with the Environmental Test Equipment
- (2) Programming the Microprocessor system for the required test profile.

B3.1 SYSTEM INTERFACES

The Microprocessor System interfaces electrically with three test items:

- (1) Temperature - humidity chamber
- (2) Vibration System
- (3) Test article support equipment.

B3.1.1 Temperature - Humidity Chamber Interfaces

There are two types of interfaces between the Microprocessor System and the temperature humidity chamber:

- (1) Temperature data inputs
- (2) Environment control outputs

Since the Microprocessor System provides complete control of the test chamber environment, it must receive feedback data from the chamber on measured temperature and humidity. The data, that is compared with the reference profile, will initiate a control action if required. The form of feedback data is two thermocouples located in the chamber to provide measured chamber air temperature (dry bulb temperature) and humidity-related temperature (wet bulb temperature). The wet bulb thermocouple must be located under the muslin sock and kept moist by the chamber's water system. The two thermocouples are interfaced directly with the Microprocessor A-D module or through an external reference junction compensator if required by the A-D module.

Since the chamber environment is completely controlled by the microprocessor, all of the following chamber functions must be interfaced with the microprocessor:

- (1) Temperature Air Circulator - which turns on the chamber heat exchange blower and serves as a master switch for all heaters and coolers.
- (2) Water Supply - fills or drains the chamber water system.
- (3) Air Heater - activates the heater relays supplying power to the coil heaters in the chamber heat exchanger.
- (4) Air Cooler - activates compressor relays or refrigerant valves to provide cooling in the chamber heat exchanger.
- (5) Water Heater - activates relay to heating coils in the water pan to add moisture to air for controlled humidity.
- (6) Water Cooler - activates compression relays or refrigerant valve to cool the water pan to remove moisture from the air for controlled humidity.

The microprocessor relays are wired in parallel with each of the chamber switches controlling these functions. During a Microprocessor-controlled test, these switches are left open on the chamber, thus shifting control to the microprocessor relays. With the Microprocessor System disconnected or relays open, the switches will function normally for manual operation of the chamber. See Fig. B-2 for a diagram of these interfaces.

Care should be exercised in sizing the microprocessor relays for the required chamber loads. These relays are, in turn, activated by small reed relays located on the microprocessor D-A module. These logic-controlled reed relays function as switches for an external DC supply to activate the Microprocessor System control relays.

B3.1.2 Vibration System Interface

There are two types of interfaces between the Microprocessor System and the vibration system:

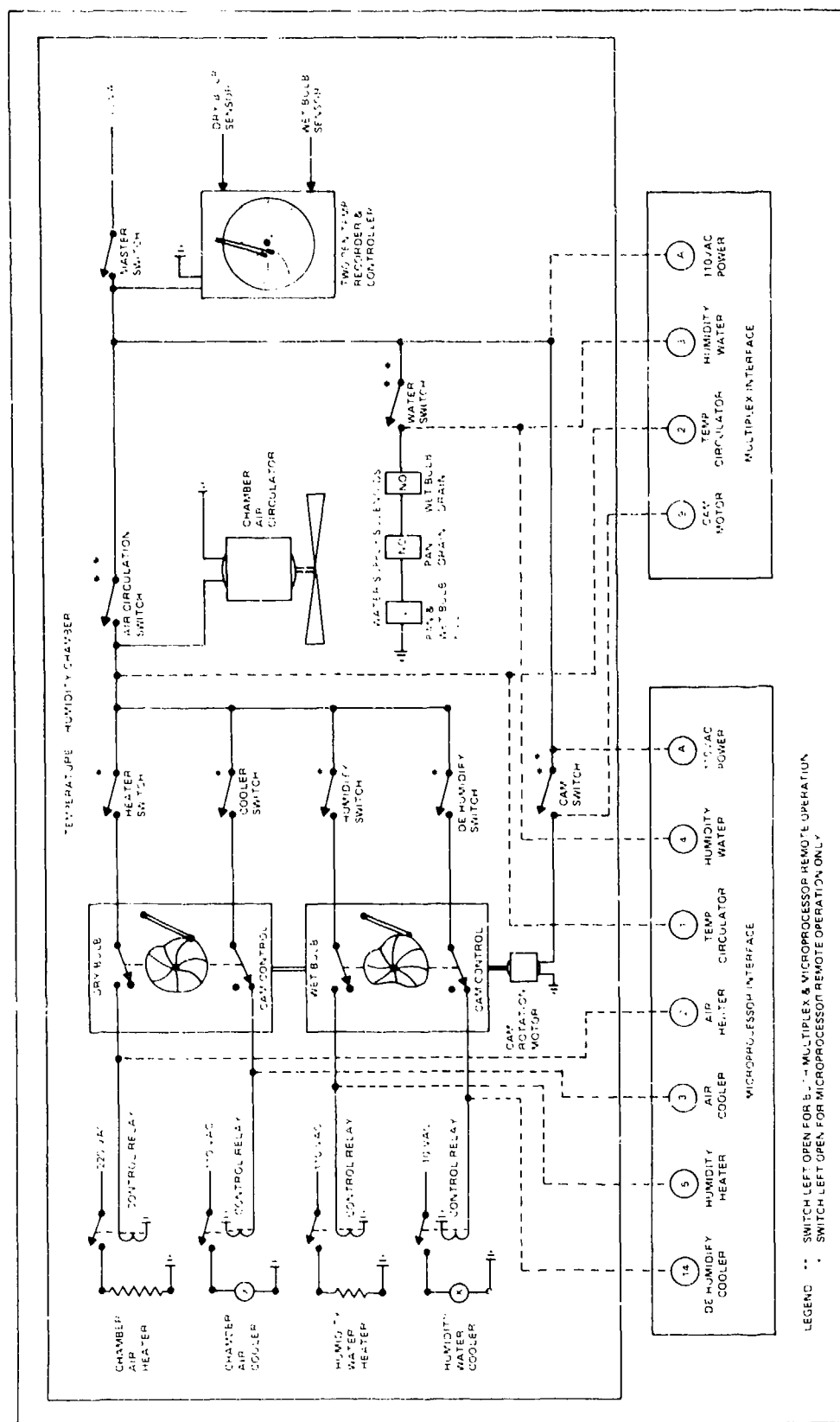


Fig. B-2 Test Chamber Interface Diagram

- (1) Vibration data input
- (2) Vibration signal output.

While the Microprocessor System does not provide servo-control of the random vibration level, it does monitor and record the acceleration, signal out-of-tolerance test levels, and shut down the exciter system when test levels are exceeded. This is accomplished using a control accelerometer mounted on the test fixture and connected through a charge amplifier to a True-RMS meter. The DC output of the charge amplifier is connected directly to the Microprocessor A-D module. This data is sampled by the computer, compared with the program references, and printed on the system display. If the measured acceleration exceeds the programmed abort level, a control relay is activated to shut down the exciter system. This shutdown relay must be wired into the exciter's safety shutdown system.

Most exciters are equipped with two internal safety switches: an overtravel switch and an overheat switch. Both of these switches are normally closed. When open, they drop out a system relay in the power amplifier which must be manually reset before testing can be resumed. The Microprocessor System vibration dump relay must be wired in series (normally-closed contacts) with either of these exciter safety circuits. A normally-open bypass switch should be provided to cut out the microprocessor system when it is not being used.

These vibration interfaces are also shared with the Microprocessor system tape deck. Since the Microprocessor system is intended to operate unattended, it was considered prudent to have a record of the control accelerometer prior to and at a system shutdown. The right input channel is therefore wired in parallel with the True RMS meter to continuously record the control accelerometer signal. In order to stop the recording of the signal at the initiation of a shutdown, the tape deck power or drive solenoid is wired into the vibration dump relay. This preserves the recorded acceleration signal for 12 minutes prior to shutdown (length of tape-loop cartridge). The data can then be played back through an analyzer to document the conditions of the shutdown.

The input for the vibration system is provided by the left channel of the Microprocessor system tape deck. In order for the Microprocessor system to program changes in test level, the random noise signal from the tape deck is passed through an attenuator network, controlled by the Microprocessor, and directly to the audio input of the exciter power amplifier. [As noted previously, older exciter systems may require a preamplifier between the tape deck and the power amplifier.]

The attenuator network is controlled by individual Microprocessor control relays. One approach is to wire a resistor in series with the audio input under control of the vibration control relay. This resistor is sized to provide the lowest level of vibration required by the test profile. Higher levels of vibration are attained by assigned control relays to switch resistors in parallel with this series resistor, thus lowering the effective circuit resistance in the audio path. A separate control relay is assigned to each level of vibration required by the test profile. This circuit has the advantage of the vibration "on" relay defaulting to the lowest vibration level in the absence of any other vibration relay activations.

In selecting these audio control relays to be used with the D-A module, the use of solid-state AC relays should be avoided as the load voltages are often only 100 or 200 mV.

See Fig. B-3 for a diagram of all vibration interfaces.

B3.1.3 Test Article Support Equipment Interfaces

The microprocessor D-A module provides 16 channels of control relay switching on the D-A module. Six channels are used in the control of the temperature-humidity chamber, and five channels are used in the vibration system. This leaves five control relays available for interfacing with the test article support equipment. These control relays can be wired in parallel with support equipment switches to turn on power to the test article, turn on cooling air when required, and initiate test functions such as high and low input voltage. The control relays used to interface the equipment with the D-A module should be sized for the anticipated loads of the support equipment.

B3.2 SYSTEM PROGRAMMING

The procedure for programming the Microprocessor System can be divided into two sections:

- (1) Tape programming (synthetic random voltage)
- (2) Microprocessor program.

B3.2.1 Tape Programming

The tape random technique is completely described in NAVMAT P-9492. Therefore, in this section, we will outline modifications to the procedure which are necessitated by the unique requirements of the Microprocessor System and the test profile. The significant differences between the screening test of NAVMAT P-9492 and the Reliability Demonstration Test of MIL-STD-781C can be summarized for the Reliability Demonstration Test as follows:

- (1) Single test article and setup used for entire test program.
- (2) Several different levels of vibration required.
- (3) Test article vibrated over a wide temperature range.

B3.2.1.1 Sine Transfer Characteristics - The sine transfer characteristics are recorded in the same way as described in NAVMAT P-9492. However, because of the wide temperature range of the test, it is recommended that the sine transfer characteristics be recorded at the two temperature extremes in addition to the normal room temperature sweep. [With some types of mounting systems, thermal expansion can cause significant shifts in the major resonant frequencies.]

It is also recommended that, because of the requirement for different test levels, a linearity check be made by recording sine sweeps at both 1.0 g and 3.0 g, from 20 to 2000 Hz.

Therefore, the sine tape will have the following sine sweep recorded on it:

- (1) 1.0 g - Room temperature
- (2) 3.0 g - Room temperature
- (3) 1.0 g - Lowest temperature
- (4) 1.0 g - Highest temperature.

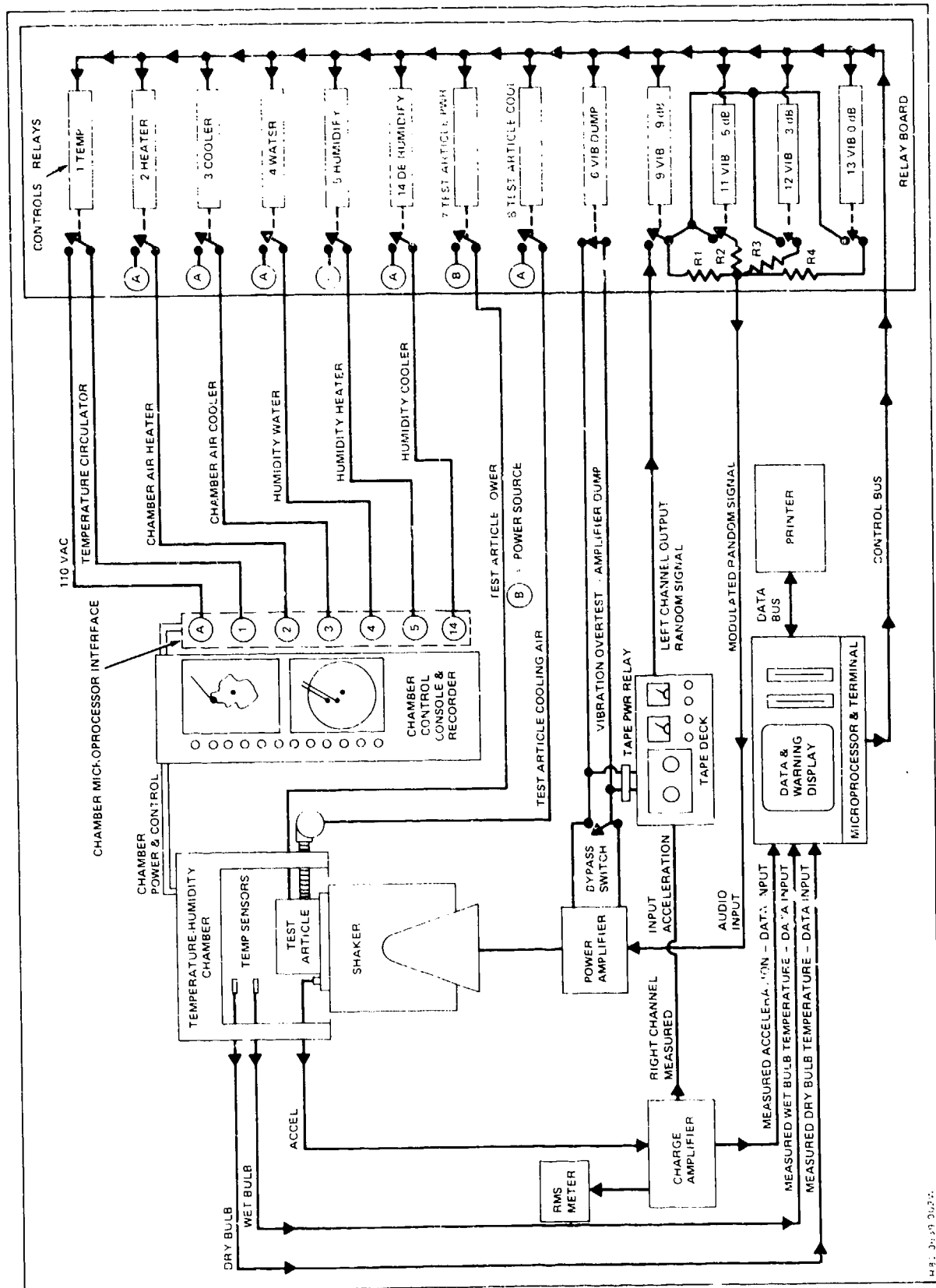


Fig. B-3 Microprocessor Test System

Since these four sweeps will require approximately 40 minutes of tape, the "end-less-loop" type of cartridge cannot be used. These sine sweeps should be made with standard cassettes. While a standard cassette will operate normally in the tape deck, it can only be used on one side. This is because the deck has been modified to use only track #1 and #4 to provide widest head separation during simultaneous playback and record. A typical sine transfer curve is shown in Fig. B-4.

B3.2.1.2 Preparation of Synthetic Random Tape - The analytical calculation of the synthetic random voltage is performed in essentially the same manner as described in NAVMAT P-9492. Each of the four sine sweeps are played through a real-time analyzer and the sine transfer function (E/g) determined. If there are minor differences noted in the function at the low and high temperature, the two functions can be averaged. Compensation factors for linearity (based on the two room-temperature sine sweeps) can be applied to this averaged function. Since the same test article is used throughout the test program, no compensation factors for variance are required.

If, however, the differences in the transfer function due to temperature or linearity are large enough to cause out-of-tolerance amplitudes at any temperature or test level, separate synthetic random spectrums may be required. Problems in overall linearity can be compensated for when choosing the resistors for the attenuator network (see par. 4.1). Large differences in the temperature transfer functions, requiring separate synthetic random spectrums, can be accommodated by recording both spectrums on the "end-less" loop cassette and programming the Microprocessor to switch between them as the profile requires. The recording of the control accelerometer could be handled on a separate tape deck.

B3.2.1.3 Recording the Random Tape - The synthetic random noise is recorded in essentially the same manner as outlined in NAVMAT P-9492, with the following exceptions.

Since verification of the test setup using the recorded sine sweep is only required at the start of the test program, the sine sweep is recorded on a different tape cassette than the random program. If the test laboratory has a spectrum analyzer, verification of the test setup can be made directly with the random tape.

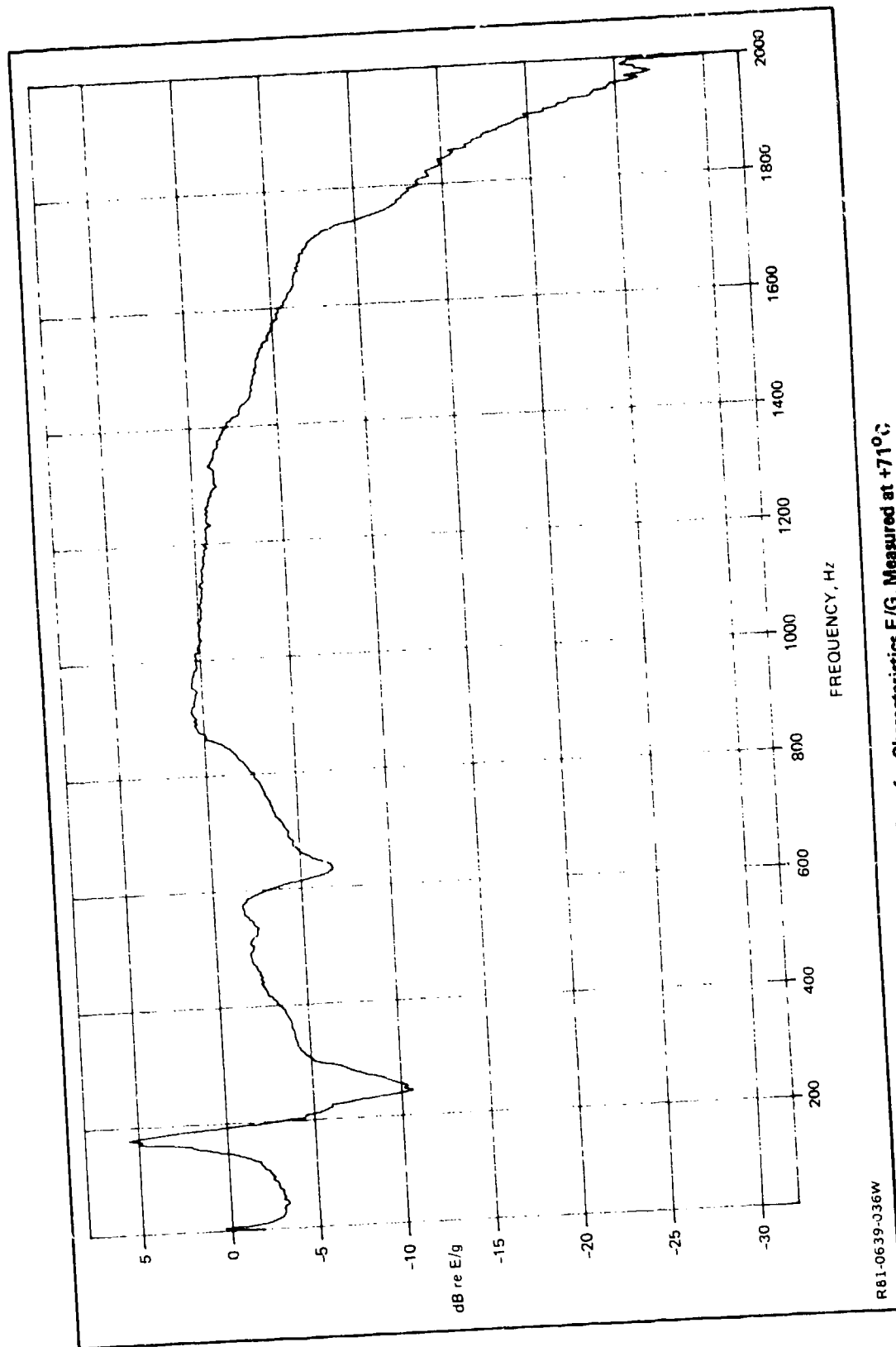


Fig. B-4 Sine Transfer Characteristics E/G, Measured at +71°C.

R81-0639-036W

As noted previously, the "endless-loop" type cassette is used for the synthetic random voltage. [This method eliminates the need for any time synchronization between the tape deck and the Microprocessor.] The length of the loop on the cassette is twelve minutes. The random equalization system is programmed with the calculated synthetic voltage. A typical random voltage curve is shown in Fig. B-5. To record the tape, the random equalization system is run in a closed-loop mode (the output is fed back into the control accelerometer loop) with the output parallel to the input of the tape deck left channel. Before the tape drive is started, the left channel recording level is adjusted to 0 dB.

The recording is started by actuating the tape deck drive with the deck in the record mode. At the conclusion of about 13 minutes, the recording can be terminated by pressing the tape deck STCP switch. The tape loop is recorded in 12 minutes. Because of the nature of the system, there are two brief (less than a second) interruptions in the recorded noise - one at the tape splice joining the beginning and ending of the loop, and the other at the point the tape deck is stopped. These interruptions drop the exciter vibration level for only about two seconds in every 12 minutes of operation - not considered significant in testing of these durations.

If separate synthetic random voltages are required because of temperature differences, the right tape channel could be recorded in the same manner.

B3.3 MICROPROCESSOR PROGRAMMING

Five programs were written to prepare the test instrumentation and conduct environmental tests. The function of each program and the logic used to develop the program is presented.

B3.3.1 CALIBRATE Program

Upon execution, this program will print out one of three inputs required to monitor the test profiles. The test operator selects either channel 0, dry bulb temperature, channel 1, wet bulb temperature, or channel 8, DC voltage representative of the rms acceleration.

Once a channel has been selected, program flow is directed to one of three sections shown in the flowchart, Figure B-6. During this phase of program

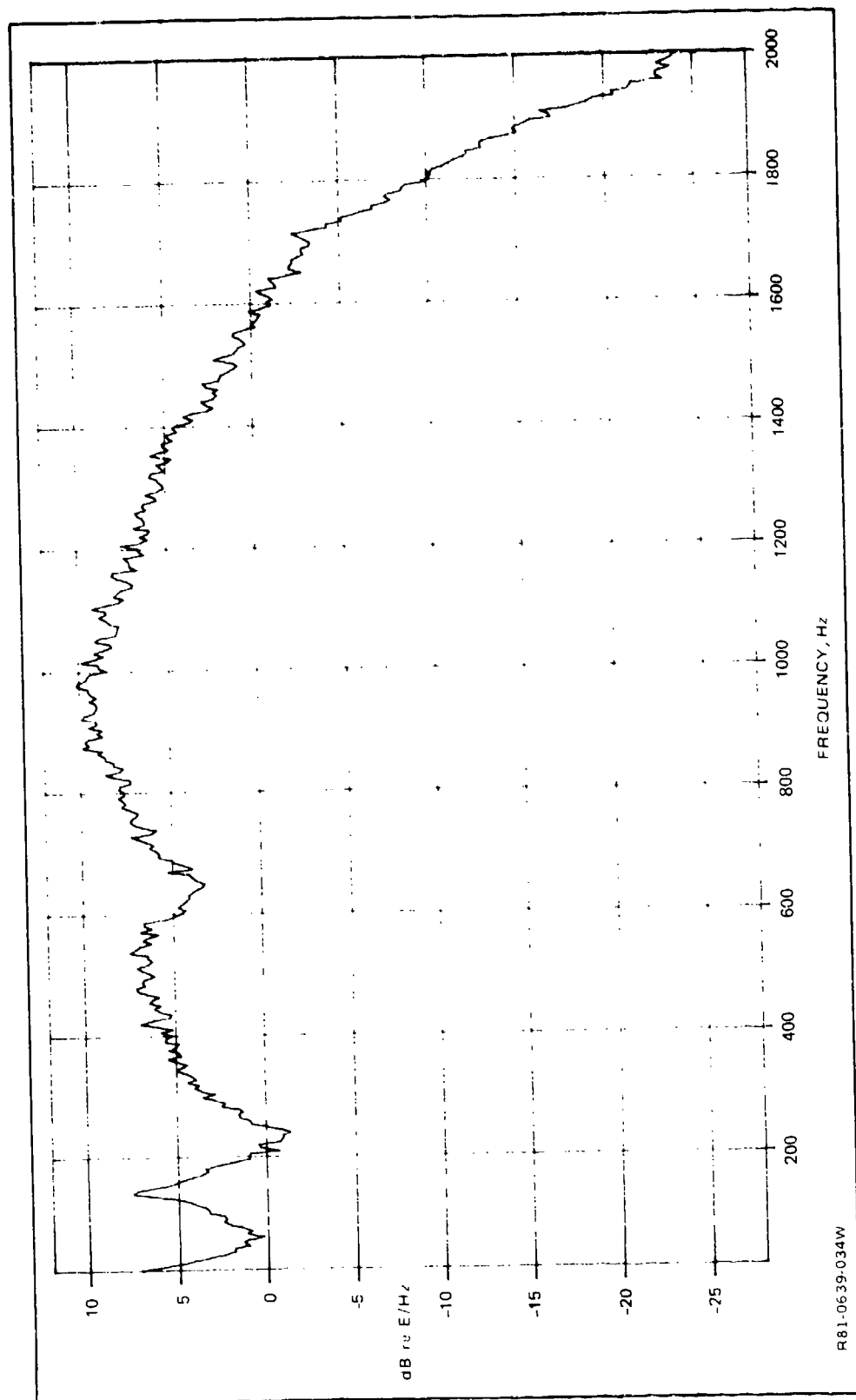


Fig. B-5 Microprocessor System: Recorded Random Voltage, Temperature Compensated

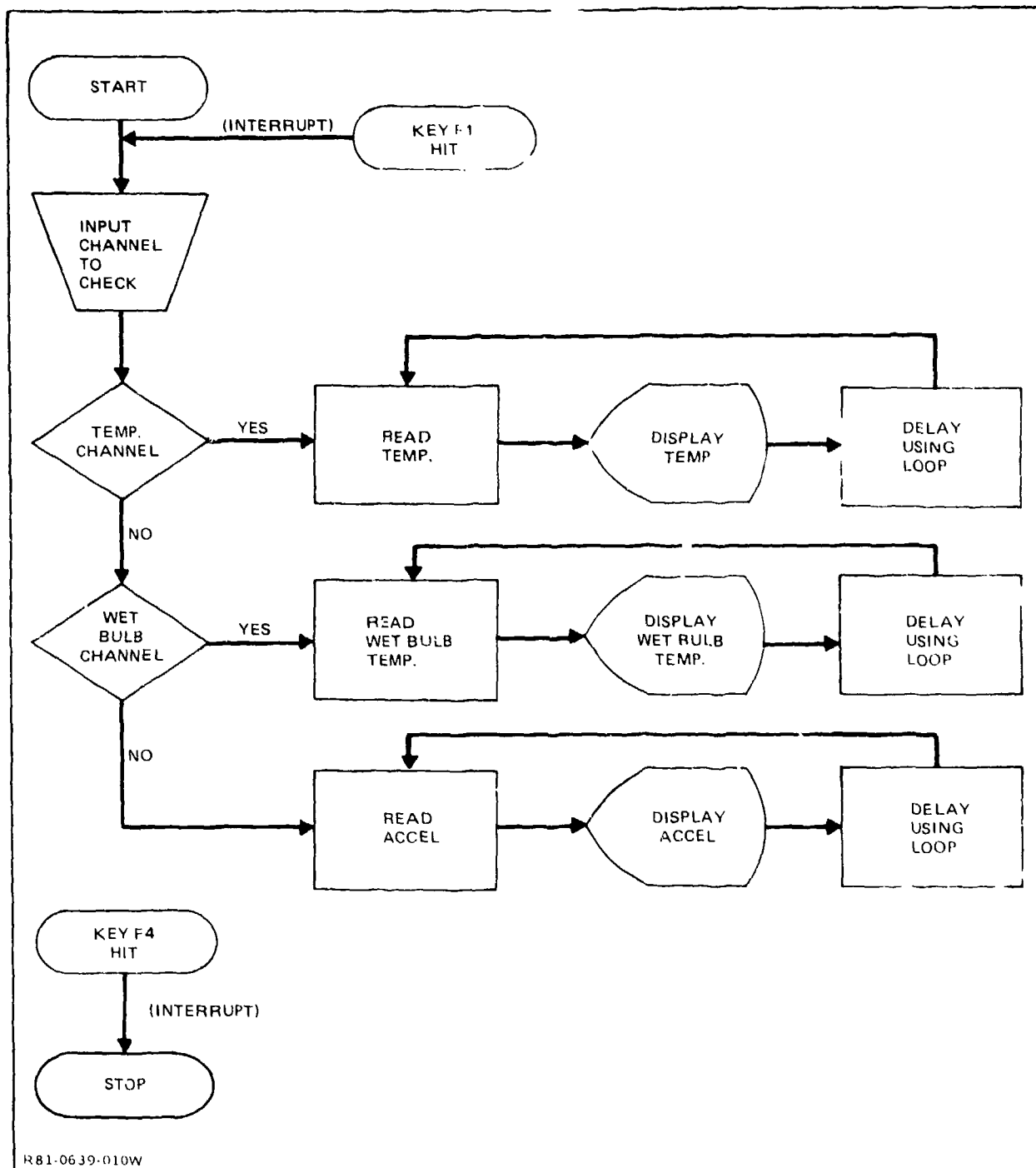


Fig. B-6 CALIBRATE Flowchart

execution, the value is read and displayed. The program then executes a small loop to perform a time delay prior to reading the input again.

Depressing Key F1 generates an interrupt which restarts the execution of the program and a new channel may be selected. Depressing Key F4 generates an interrupt which transfers program control to a subroutine that terminates the program.

B3.3.2 SETUP Program

A flowchart of program SETUP is presented in Figure B-7. This program is used to activate switches that are connected to the environmental test chamber and vibration exciter. The operator inputs the number of switches and which switches are to be activated. Integers are calculated and written into two key memory locations that turn on the switches selected. The program then executes an indefinite loop which can be terminated through an interrupt by depressing Key F1 or F4. Key F1 restarts the program while Key F4 terminates program execution, and resets all switches for the start of the Reliability Demonstration test.

B3.3.3 DEMO Program

The DEMO program was written to monitor and control the environmental test system to specific thermal, humidity and vibration profiles for a test period of 45 minutes. A flowchart of the program is presented in Figure B-4. The program operates in any one of three phases, STABILIZATION, MONITOR/CONTROL and HOLD. A description of each phase follows.

B3.3.3.1 STABILIZATION - As described in Figure B-8, upon start of program execution, the operator inputs the start time of the test cycle. The operator has the option of starting at any point within the 45 minute cycle time. Once the start time has been input, temperatures and acceleration are monitored and the required values are determined by the program. The measured and required dry bulb temperatures are displayed. A comparison is made to determine if the two values are within $\pm 1^{\circ}\text{C}$. If the measured value is out of tolerance, switches are activated to cool or heat the chamber as required. This procedure is repeated until the two values are within tolerance, at which time program control is transferred to the MONITOR/CONTROL phase.

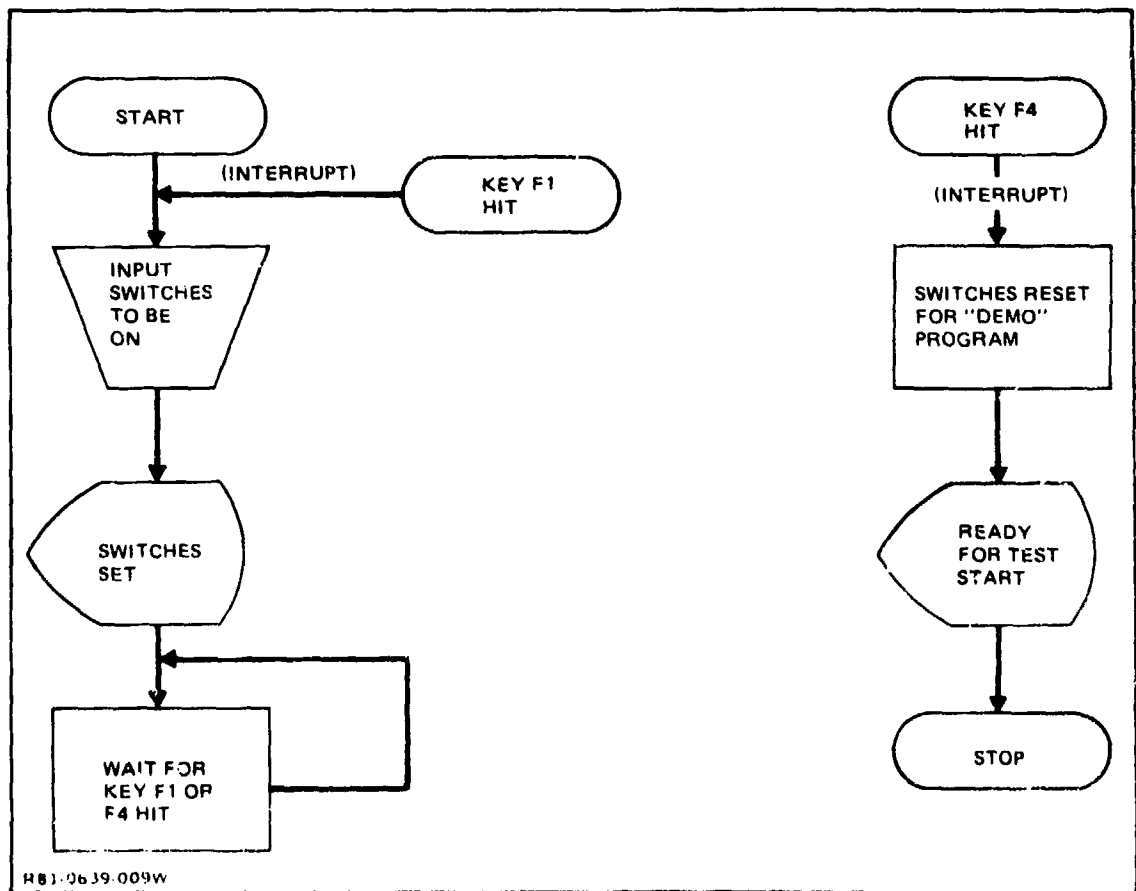


Fig. B-7 SETUP Flowchart

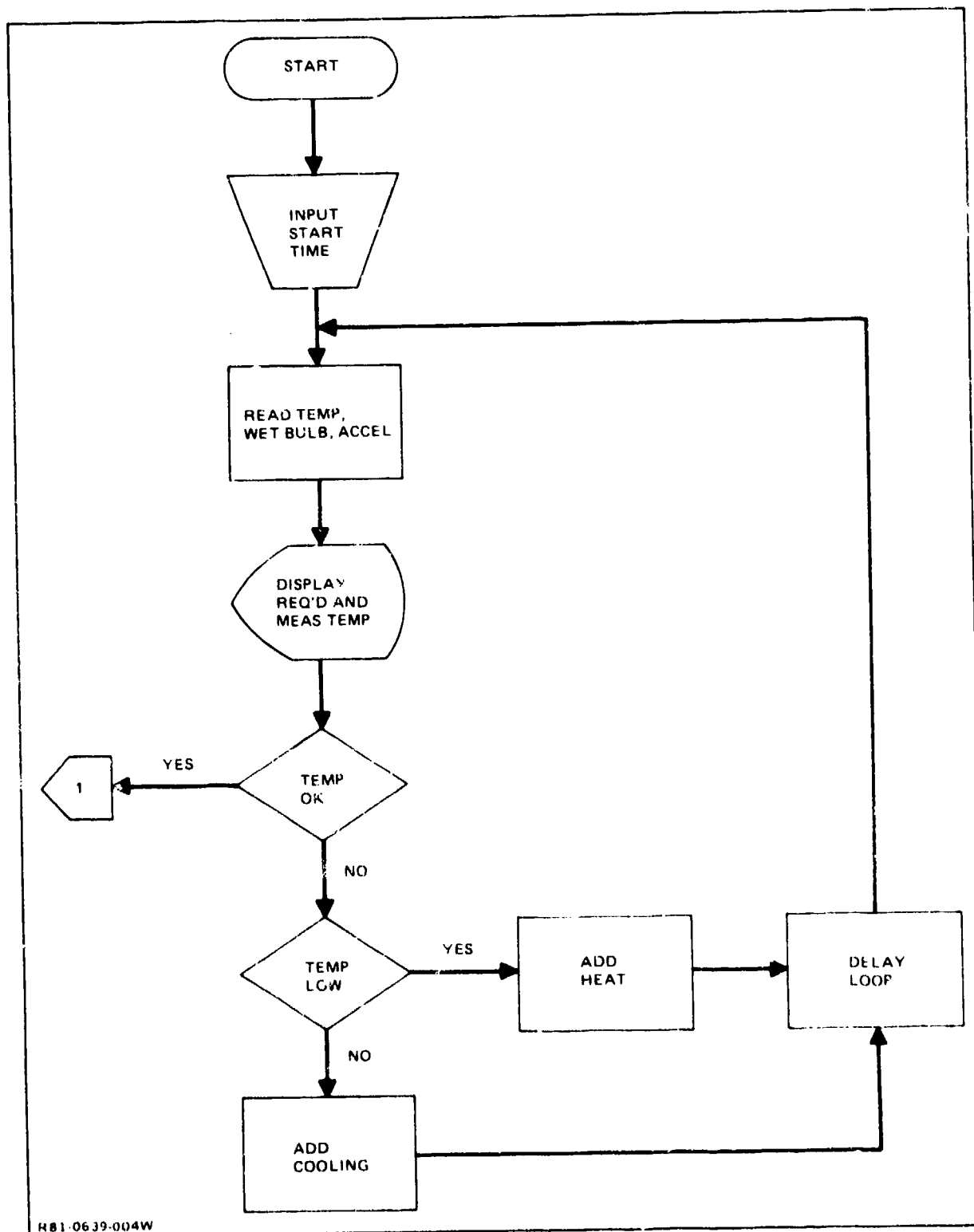


Fig. B-8 DEMO Flowchart: Stabilization Routine

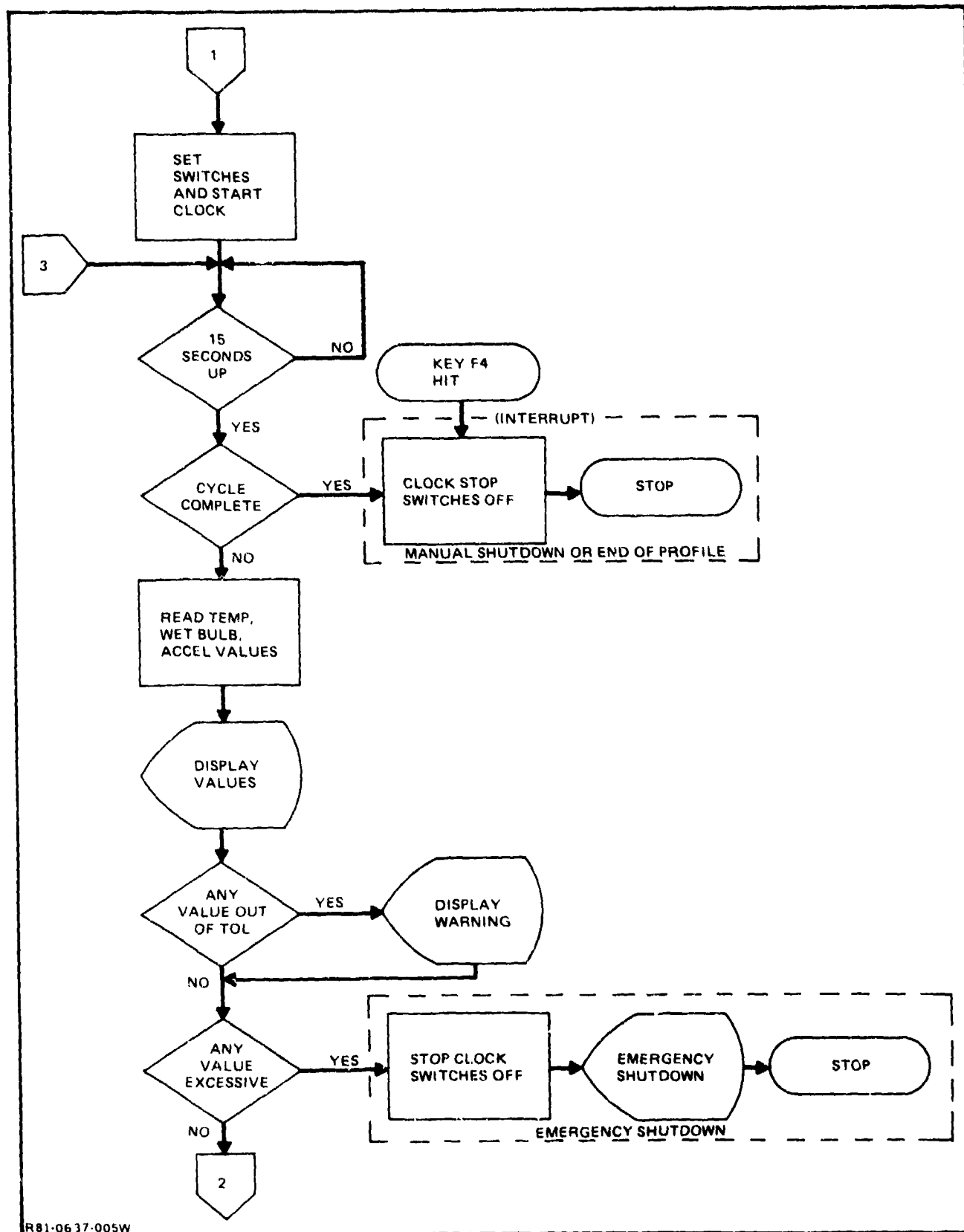
B3.3.3.2 MONITOR/CONTROL - The monitor/control phase of the program is initiated by setting all switches required at the input start time and starting the microprocessor clock, Figure B-9. The program then executes through a complete loop every 15 seconds. At any time during execution of this phase of the program, an interrupt may be generated to stop the program by depressing Key F4, or transfer control to the "HOLD" phase, by depressing Key F1.

In executing the loop, a check is first made to determine if the 45-minute cycle is complete. A completion of the cycle stops the clock and switches off the environmental test instrumentation. The program is then terminated.

Next, the input transducers are monitored and their readings are displayed along with the required values. Comparisons are made and, if required, out-of-tolerance warnings are displayed. An excessive out-of-tolerance condition leads to an emergency shutdown and terminates the program. The loop is completed by activating switches based on the cycle time and the dry bulb and wet bulb temperature readings.

B3.3.3.3 HOLD Program - Figure B-10 presents a condensed flowchart of the HOLD portion of program DEMO. As previously mentioned, the HOLD phase of the program is executed through an interrupt by depressing Key F1. Once this key is depressed, control is briefly transferred to a subroutine which changes an integer variable from zero to one and holds the time constant. The program then executes the MONITOR/CONTROL portion of the program. However, since the required temperatures and acceleration are based on the constant time point, the program will monitor and control the input parameters to those required at the time Key F1 was depressed. The integer value of one informs the program that the HOLD condition is on and that monitor/control is based on one time point, not the test profiles.

The HOLD phase is terminated by depressing Key F1 again. This transfers control to the same subroutine but resets the integer value from one back to zero. Upon return to the MONITOR/CONTROL portion of the program with a zero integer value, the program resumes following the test profile. As described in the flowchart, depressing Key F1 an odd number of times transfers control to the HOLD routine and an even number of times to the MONITOR/CONTROL routine.



R81-06 37-005W

Fig. B-9 DEMO Flowchart: Profile Monitor and Control

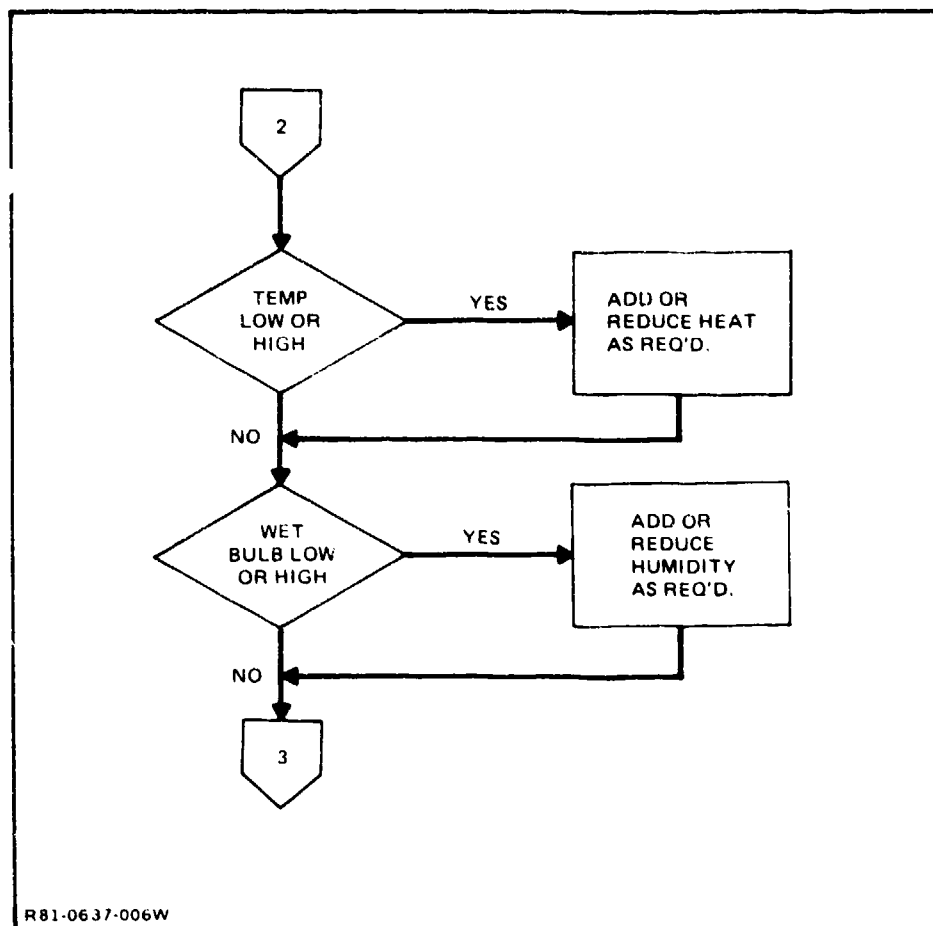


Fig. B-9 DEMO Flowchart: Profile Monitor and Control (Cont.)

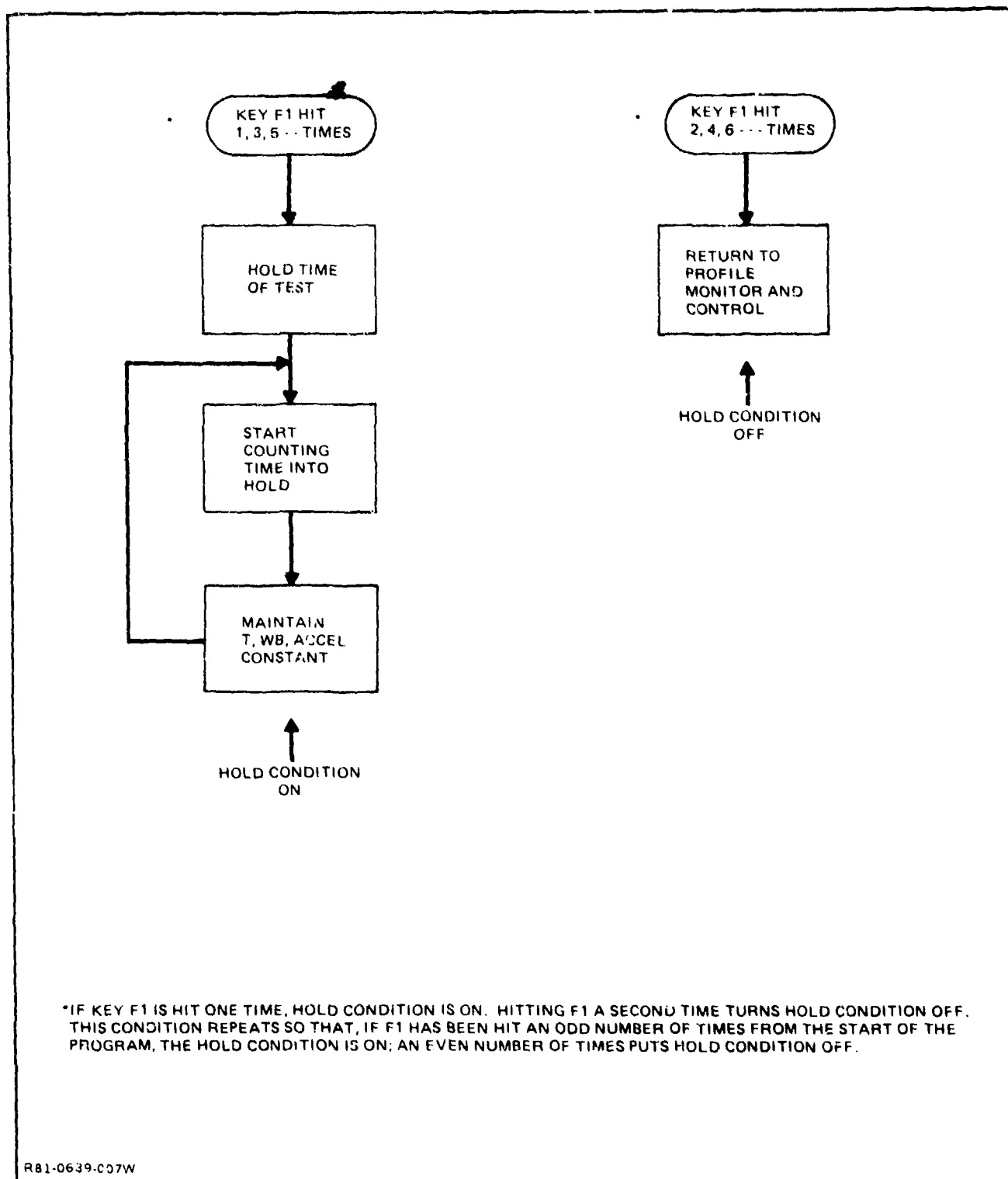


Fig. B-10 DEMO Flowchart: Hold Routine

B3.3.3.4 Determination of Control Cycle Parameters - The configuration of the control cycle is a variable related to the test chamber response, the thermal mass of the test article, and the temperature range of the test. There are three parameters that should be examined:

- (1) Length of control band (sample rate)
- (2) Width of control band
- (3) Proportional control

The length of the control band is the time between microprocessor samples. As the sample data is received, the microprocessor initiates the required control action (such as switching on the air heater). The heater remains on until the next sample is taken and the microprocessor turns it off (if temperature has exceeded the upper control temperature). If the time between samples is too long, large over- and under-shoots of the temperature will result.

The width of the control band is the delta temperature above and below the reference set temperature that initiates the control action. This establishes a dead band around the set temperature where both heating and cooling are switched off. Correct choice of width should eliminate any control cycling around the set temperature.

Proportional control is a control method used to minimize over-shoot during temperature transitions and excessive cycling around the set temperature. Since heating and cooling is an on/off control operation, proportional control usually takes the form of proportioning the percentage of time the control is on when it is within a temperature band around the set temperature. [For example, if the control cycle is 30 seconds, 40% proportioning would limit the heater "on" time to 12 seconds whenever the temperature is within 10° of the set temperature.]

Since each of these three control parameters have an interacting effect on the control of temperature, it is suggested that only the first two (length and width of control band) be initially included in the test program. In order to supply values for these parameters, it is suggested that an empirical method be applied. The approach will consist of running the test chamber under microprocessor control with the test article or an equivalent thermal mass installed in the chamber.

It is recommended that, for the initial test run, the length of the control band (sampling rate) be set at 30 seconds and the band width set at $\pm 30\%$ of the required tolerance band (i.e., $\pm 1^\circ$ for a required tolerance of $\pm 3^\circ\text{C}$). The chamber should be run through the test profile and any problems with test control noted. The program can then be revised and the test repeated until the required test tolerances are achieved.

As examples of corrections that can be applied, we can examine a few typical problems that may be encountered:

- (1) Cycling of control with positive and negative tolerance exceedance - corrective action would be to decrease the length of the control band from 30 to 15 seconds.
- (2) Positive tolerance exceedance on temperature transitions and cycling - corrective action would be to change the control limits from $\pm 30\%$ of the tolerance band to $+10\%$ and -50% of the tolerance band.

If, after several adjustments of these two parameters, out-of-tolerance temperature cycling still occurs, consideration should be given the third alternative of programming proportional on and off time during a program cycle.

B3.3.4 TROUBLESHOOT Program

Program TROUBLESHOOT, Figure B-11, allows the operator to control any sequence of four parameters to values input at the keyboard. The parameters are:

- Dry bulb temperature
- Wet bulb temperature
- Acceleration (four possible values)
- Test Article Power (On or Off).

The program operates on a 15-second loop, wherein measured parameters as well as the required values are displayed. An out-of-tolerance condition will result in switches being activated to correct the condition. An extreme out-of-

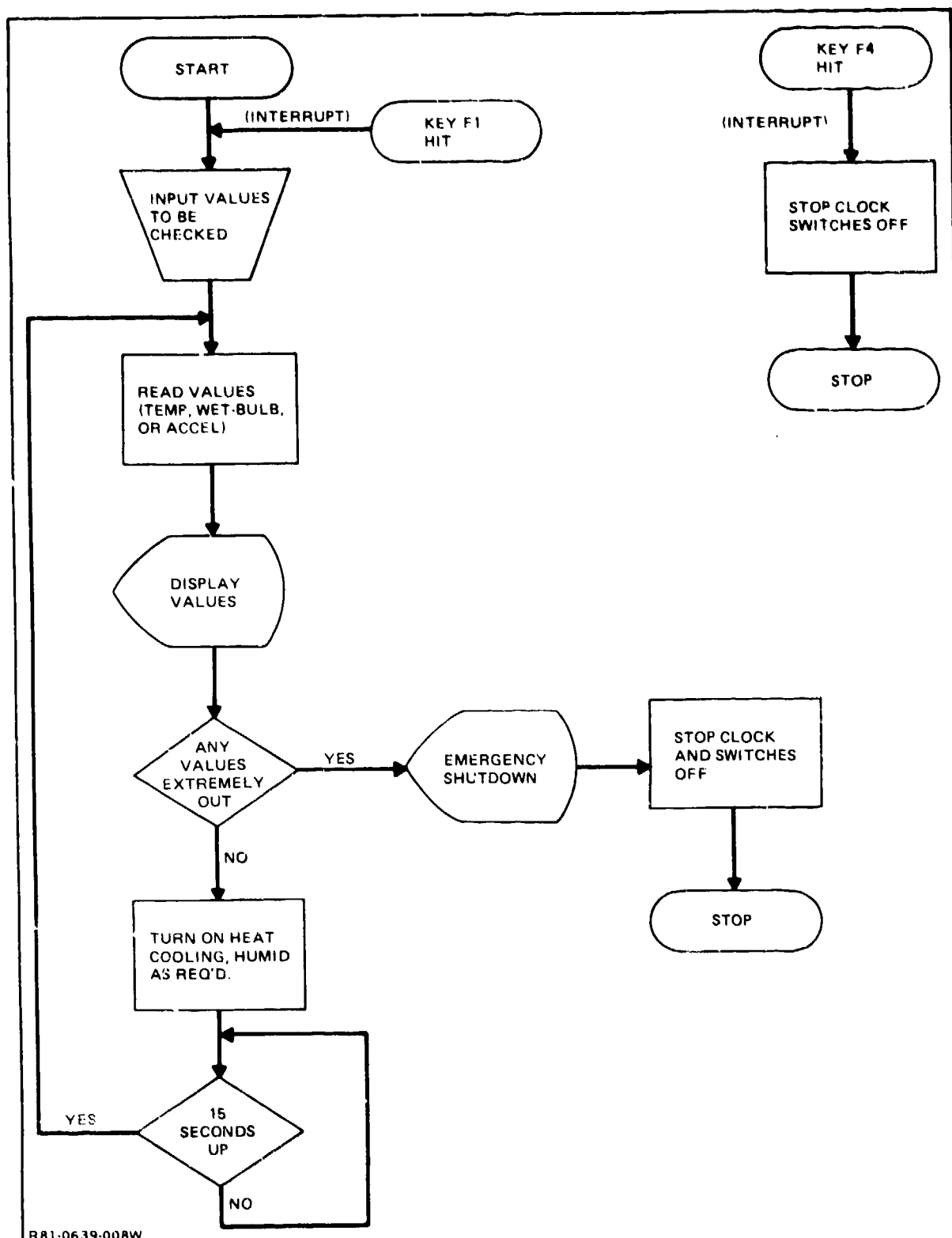


Fig. B-11 TROUBLESHOOT Flowchart

tolerance condition will result in an emergency shutdown and terminate the program. An interrupt will restart the program by depressing Key F1, or terminate the program by depressing Key F4.

B3.3.5 RELDEM Program

Program RELDEM was written to perform the monitor/control functions for an eight-hour test period. The program and flowcharts are identical to DEMO except for a few minor changes.

The data required to run the program reflects the new test profiles for the eight-hour cycle. Some additional instruction statements were added to monitor and control the wet bulb temperature over that portion of the test cycle. The DEMO program performed this function over the entire 45-minute test cycle.

B4 - TEST OPERATIONS

The performance of reliability demonstration tests with the Microprocessor system can be divided into three sections:

- (1) System calibration
- (2) Testing with the system
- (3) Test data

B4.1 SYSTEM CALIBRATION

System calibration can be divided into two areas:

- (1) Vibration system - which encompasses the calibration of the accelerometer input as well as the attenuator network for the vibration output
- (2) Temperature sensors - which covers the calibration of the two thermocouple inputs

B4.1.1 Vibration System Calibration

The first phase of the calibration is to determine the value of the resistors in the attenuator network. While this can be approached analytically, the more direct empirical approach will yield quicker results. As noted previously, a control relay is assigned to each level of vibration which is required. The lowest level also functions as the Vibration Enable switch.

A variable resistor in the range of 100K ohms is wired in series with the audio output of the tape deck, through the "vibration enable" control relay, and on to the power amplifier input. (See schematic in Figure B3). The synthetic random tape is then played through the system and the variable resistor adjusted until the true-rms meter reads the lowest required test level.

The other control relays for vibration are wired to place a variable resistor in parallel with this "lowest level" resistor. Each of these control relays can be activated in turn, and its variable resistor adjusted until its required amplitude

is read on the true-rms meter. This is a one-time adjustment and need not be repeated for individual test runs. Individual control relays can be conveniently activated by the Microprocessor, using the SETUP program described in Par B3.3.2.

The second phase of the vibration calibration is to adjust the vibration channel of the A-D module to read directly in g-rms. As noted previously, the DC output of the accelerometer charge amplifier is connected to the A-D module. This signal is proportional to the average value of the measured acceleration. In order to calibrate it in terms of G-rms, a random noise source is used with a true-rms meter as the reference.

The most direct method is to operate the exciter at the full test level and adjust the attenuator resistor on the vibration channel of the A-D module until a reading of the G-rms (using the true-RMS as reference) is printed on the microprocessor's CRT display. Readouts from the A-D module channels can be displayed on the CRT using the CALIBRATE program described in Par B3.3.1. [Note: The zero and span of this channel should be adjusted per manufacturer instructions prior to this G-rms calibration.]

B4.1.2 Temperature Sensor Calibration

The two A-D module thermocouple channels are also calibrated using the CALIBRATE program. However, rather than using a reference thermocouple to calibrate these channels, the thermocouples are disconnected from the A-D module and a DC input from a precision millivolt source is applied. Using the NBS reference tables for the type of thermocouples being used, the millivolt equivalent for the highest and lowest temperature which the thermocouple is expected to see is determined. These voltages are applied to the A-D module channels and the zero and span adjustment pots are tuned (per manufacturer's instructions) until correct readings in degrees centigrade are obtained on the CRT display. The millivolt source is then disconnected and the two thermocouples reconnected to the A-D module.

B4.2 TESTING WITH THE SYSTEM

Test runs with the system encompass the initial setup of the test, test operations, and troubleshooting routines which can be accomplished with the system.

B4.2.1 Test Setup

The most important aspect of the test setup is assuring that the mechanical and electrical configuration of the exciter system is identical to that utilized in the recording of the sine transfer function. With the setup complete, this can be verified by playing the sine tape back through the exciter system. This verification procedure is explained in detail in NAVMAT P-9492. If a spectrum analyzer is available to the laboratory, verification can be made using the random tape and SETUP test program.

The test chamber must be configured for the start of the test. This should include:

- Main power switch on
- Air circulator, humidity water, chamber heater, chamber cooler, humidify and de-humidify switches off
- External coolant (LN_2 , CO_2 , etc) valve open if used.

The Microprocessor system must be configured for the start of the test. The power switch of the microprocessor and printer should be turned on. When power is applied to the microprocessor, it sets the control relays in a random fashion. Therefore, the first step must be to set all control relays to their off or zero condition. This and subsequent steps utilize the terminal of the microprocessor and, as such, may be unique to the microprocessor used in the system. Equivalent procedures can be derived for whatever system use.

<u>Description of Procedure</u>		<u>Terminal Entry</u>
(1)	Initialize control relays to off	ECFE 00 ECFF 00
(2)	Set printer control	; Z 01
(3)	Insert program disk in left drive	
(4)	Load disk operating system	XDOS

The Microprocessor System is now ready. Any of the BASIC test programs on the disk can be called up and run.

The vibration system must be configured for the start of the test. This should include:

- Exciter in operational mode (field current up)
- Exciter amplitude control off
- Bypass switch for exciter shutdown off
- Charge amplifier in operate mode
- True-rms meter on.

The tape deck should be loaded with the "endless loop" tape cartridge (12 minutes of synthetic random voltage). The left channel should be in the playback mode and the right channel in the record mode.

The final step in the setup is to adjust the exciter gain for the required full-level (0 dB) amplitude. This is accomplished with the following steps:

- (1) Load SETUP program into the processor by typing "BASICM SETUP" on the terminal. [This program, described in para. B3.3.2, allows any combination of control relays to be turned on.]
- (2) In answer to program question, type into the terminal that the following control relays should be turned on (Ref. Figure B3)
 - #6 - Vibration dump (normally closed)
 - #9 - Vibration enable
 - #13 - Vibration 0 dB test level
- (3) Start tape deck drive
- (4) Turn exciter gain control up until the required 0 dB test level is indicated on the true-rms meter. [Mark position of gain control so it can be readily reset after a test halt.]

Once the gain is properly set, the recording level on the right channel [connected to the control accelerometer] should be set to 0 dB on the tape deck VU meter using the record level control. A spectrum analysis of the control accelerometer can also be made at this time if a real-time analyzer is available.

The tape deck can be left running at this time. As noted previously, the

"endless-loop" cartridge should always be operated in a horizontal plane to avoid winding problems.

The SETUP program can be terminated by pressing the stop key (key F4). The microprocessor returns all control relays to their "off" position.

B4.2.2 Test Runs with the System

To initiate the test program, the operator types the name of the program into the terminal. The microprocessor finds the program on the disk and loads it into memory. The operator types "run" into the terminal and is then asked by the program to input the starting time (with reference to the test profile) for the test. The operator types in the starting time (zero for start of test) and the microprocessor takes over complete control of the test program.

The initial phase of the test is the stabilization of the chamber air temperature to the temperature required by the test profile at time zero. The microprocessor turns on heating or cooling as required to reach the starting temperature. [This is not counted as test time by the program]. Once the starting temperature is reached, the microprocessor starts the test run.

The program is designed so that the Microprocessor operates in short sampling cycles (required for adequate control of the test chamber as explained in Para. B3.3.3.4). In each cycle, it will sample the three data measurements, compare them to the program references, and initiate any control action required. It prints on the CRT (and printer if enabled) the program time, measured data and reference value, and any values that are out of tolerance. See sample printout, Table B-1. The Microprocessor also sounds a bell alarm when any measured value is out of tolerance. Abort values for each measurement are also included in the program to shut down the system if they are exceeded.

The system, as presently configured, does not monitor any test article parameter, although it does control the timed sequence of up to five test events. The test operator, who monitors the performance of the test article, can hold or stop the program manually at any time should a problem with the test article develop.

Table B-1 Microprocessor Control System Printout

TIME=13.5		
PARAMETER	MEAS.	REQUIRED
ACCEL	2.20075076	2.34
NET BULB	42.796875	38
TEMP	69.328125	71

TIME=13.75		
PARAMETER	MEAS.	REQUIRED
ACCEL	2.32892849	2.34
NET BULB	42.78125	38
TEMP	69.828125	71

TIME=14		
PARAMETER	MEAS.	REQUIRED
ACCEL	2.28792679	2.34
NET BULB	42.984375	38
TEMP	69.747125	71

R81-0639-051W		

B4.2.3 Test Holds, Halts and Troubleshooting

In order to initiate a hold in the program, the test operator must press the terminal "hold" button (key F1). This stops the program clock and holds all the parameters at the reference level at the time the hold was initiated. [The microprocessor still samples and controls the required functions]. The microprocessor continues to print out all parameters and keep count of the time in hold. To resume the test program, the operator again pushes the "hold" button and the program proceeds from the time of the hold initiation. The operator can also elect to halt the test.

In order to halt the test, the operator presses the "halt" button (key F4) on the terminal. This sets all relays to "off" position and halts the execution of the test program. Assuming a problem in the test article has caused the program halt, the operator may want to isolate the environment causing the problem so he can troubleshoot the test article. A program titled TROUBLESHOOT has been written to accomplish this (Para. B3.3.4).

The operator loads the TROUBLESHOOT program by typing the program name into the terminal as described previously. The program then questions the operator on what environment he wants to run, and the test level to be maintained, as well as which test article function should be turned on. The program will then maintain this condition until the operator terminates it. The operator can change the test conditions by pressing the "hold" button which recycles the program to the start where the required environments are requested. Or, the operator can terminate the procedure by pressing the "stop" button which returns all control relays to their off condition and terminates the program.

The TROUBLESHOOT program allows the test operator, as an example, to run just the vibration and to increase the test level in incremental steps until the malfunction is verified and troubleshooting routines started. It should be noted that the increments of vibration level are limited to those programmed in the attenuator network.

An overtest shutdown of the program will occur if the temperature or vibration exceed the programmed abort levels. For an abort condition, the microprocessor is programmed to set all control relays to off except the chamber air circulator.

[This is left on to maintain an even temperature distribution in the chamber should testing be resumed in a short time.] After an abort, the test operator should check the printed record to determine which environment exceeded the abort limits. He should troubleshoot this system to determine the cause of the problem and correct it prior to resuming the test. A record of the control accelerometer for the 12 minutes preceding the abort is available for analysis if this is required (Para. B4.2.4).

In order to resume testing after an abort shutdown, the following steps are required:

- (1) Recycle the power amplifier to its operate mode
- (2) Adjust exciter gain control to the mark determined in the system setup (Para. B4.2.2.)
- (3) If a solenoid-operated tape deck is being used, it also must be put in its operating mode (Para. B4.2.1)
- (4) Type "run" into the terminal and specify the program time at which the test should resume.

The program then starts with the stabilization segment and proceeds in the same manner as described in Para. B4.2.2.

B4.2.4 Test Data

As noted previously, all the relevant environmental data is printed out at every control interval (typically every 15 seconds) along with the elapsed program time. These printouts continue even if the system is in hold or troubleshoot condition, so that a complete environmental test history of the test is permanently recorded. Relevant information on the performance of the test article must be maintained by the test operator in a data log.

As noted in the previous section, the tape deck continually records the control accelerometer so that a record of the last 12 minutes of the test is always available on the tape. This should be played back periodically through an analyzer to verify the test spectrum. To accomplish the playback, the tape deck must have been previously stopped and the right channel put in the play mode. The tape can be restarted and the test continued while the analysis is

made. The right channel of the tape deck must be again returned to the record mode at the conclusion of the analysis.

It should be noted that test data played back from the tape deck is uncompensated for the characteristics of the tape deck. Therefore, if the tape deck has a 6 dB roll off at 20 Hz, the test data will include this roll off. The test data, therefore, must be compensated for the characteristics of the tape deck for an accurate evaluation.